

CHAPTER 4 – RESULTS AND DISCUSSIONS

The study utilizes the Six Sigma (DMAIC) methodology for processing and analysis, building upon previous research discoveries. Six Sigma is a methodical, adaptive, quantifiable, and efficient methodology. It integrates a range of established strategies and tools that have been demonstrated to successfully reduce the quantity of faulty goods, limit errors, lessen customer complaints, and improve process capability. By adopting Six Sigma methodologies, firms may guarantee their sustained existence and augment their competitive advantage. Six Sigma adheres to a methodical technique known as DMAIC stages, which is an acronym meaning defining, evaluating, analyze, improve, and control.

4.1. Define Phase

In the define stage, the first step is to determine the sequence of activities in the remanufacturing procedures to pinpoint the stage at which the problem occurs. Regarding the pattern of activities outlined in the SIPOC Diagram, as seen in Table 4.1.

Table 4.1 SIPOC Diagram

Supplier	Input	Process	Output	Customer
Principle	Genuine Parts	Pre-Washing	Ready Core	TRIATRA
Outsource	Fabrication Parts	Dis Assembly	Surcharge	
Vendor	OEM Parts, Consumable	Washing	Service	
TRIATRA	Damage Core	Measurement & Inspection Procedure (Working Instruction, Check Sheet) Fabrication & Parts Fulfilment Assembly Performance Test Completing Painting Packaging		

The next activity is to identify products that contribute to product failure as shown in Figure 4.1.

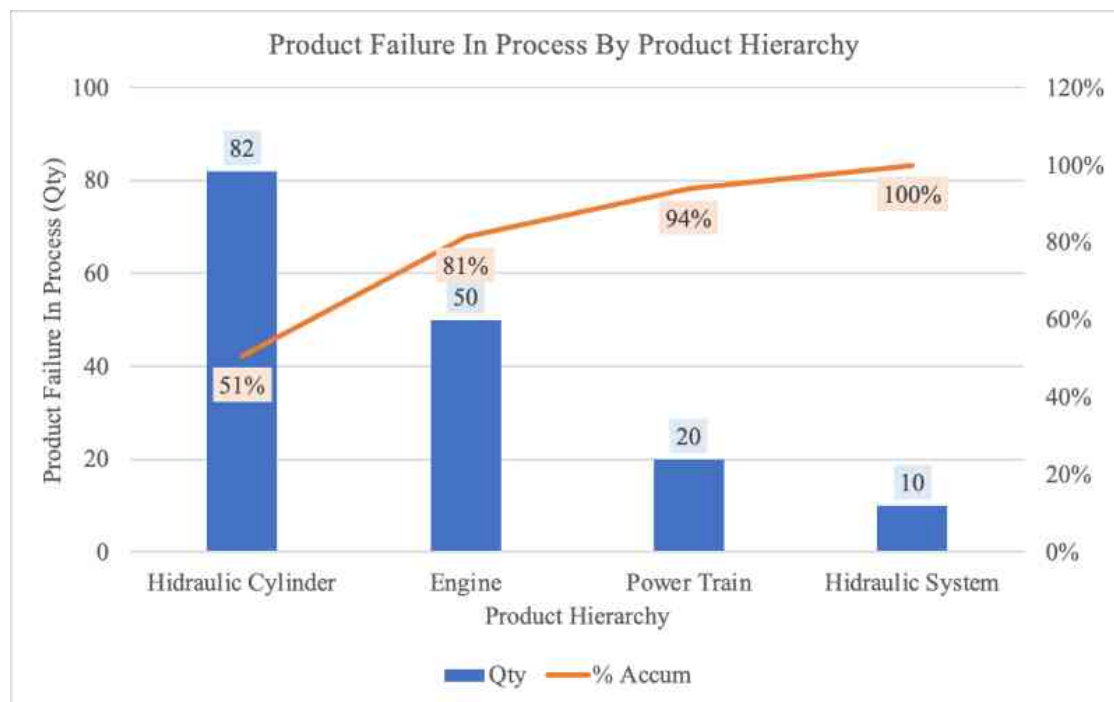


Figure 4.1 Product Failure in Process by Product Hierarchy 2023

From the figure 4.1 above, it can be concluded that hydraulic cylinder and engine products are Pareto components that contribute to product failure in process by 81% so that these products will become targets for improvement.

4.2. Measure Phase

The measurement phase is the next phase of the quality enhancement program that utilizes the Six Sigma technique. The research employs the ability of process/sigma level evaluation to assess the efficiency of the process before applying any enhancements. To decide the best way to improve the process from a technological control standpoint, it is necessary to visually express its capabilities using four block diagrams. Additionally, costs of poor quality (COPQ) is evaluated to precisely measure the financial losses incurred due to defective products.

4.2.1. Measurement of process capability or Sigma level

The process capability/sigma level calculation is based on the production data and product failure (defects) collected from January to May 2023 in the Remanufacturing process. The report from the Reman Department and Quality Control Department indicates a total production of 900 components and a total of 75 defective components. The results of this calculation are presented in Table 4.2.

Table 4.2 DPMO and Sigma of Cylinder & Engine Product

Product	Assembly				
	Production (Qty)	Defect (Qty)	Opportunity (Qty)	Total Opportunity (Qty)	DPMO
Cylinder	775	50	32	24.800	2.016
Engine	125	25	39	4.875	5.128

Product	Performance Test				
	Production (Qty)	Defect (Qty)	Opportunity (Qty)	Total Opportunity (Qty)	DPMO
Cylinder	775	50	11	8.525	5.865
Engine	125	25	14	1.750	14.286

Product	Assembly	Performance Test	Total DPMO	Tabel Z	Sigma Provision	Total Sigma
	DPMO	DPMO				
Cylinder	2.016	5.865	7.881	2,42	1,5	3,92
Engine	5.128	14.286	19.414	2,07	1,5	3,57
						3,74

4.2.2. Four block diagrams.

The four-block diagram represents a visual depiction for a process that highlights two areas for improvement: technology and control. Technology refers to the tools and techniques used in the process, while control refers to the ability to manage and regulate the process effectively (referred to as process Z). The Z_{shift} value, which reflects the control ability, and the $Z_{bench,st}$ value, that represents the ability of technology, can be calculated based on the Sigma Level of 3.74. These values are then plotted in four block diagrams to illustrate the capability of the continuing process (Z). The computations for Z_{shift} and $Z_{bench.lt}$ within the four-block diagram were as follows:

$$Z_{bench.st} = Z_{bench.lt} + 1.5 \quad (4.1)$$

$$3,74 = Z_{bench.lt} + 1.5 \quad (4.2)$$

$$Z_{bench.lt} = 3,74 - 1,5 \quad (4.3)$$

$$Z_{bench.lt} = 2,24 \quad (4.4)$$

$$Z_{shift} = Z_{bench.st} - Z_{bench.lt} \quad (4.5)$$

$$Z_{shift} = 3,74 - 2,24 \quad (4.6)$$

$$Z_{shift} = 1,50 \quad (4.7)$$

After determining the values of Z_{shift} (control ability) and $Z_{bench.st}$ (sigma level), the following stage involves creating four block diagrams to visually represent the current

process condition. These block diagrams are referred to as Figure 4.2.

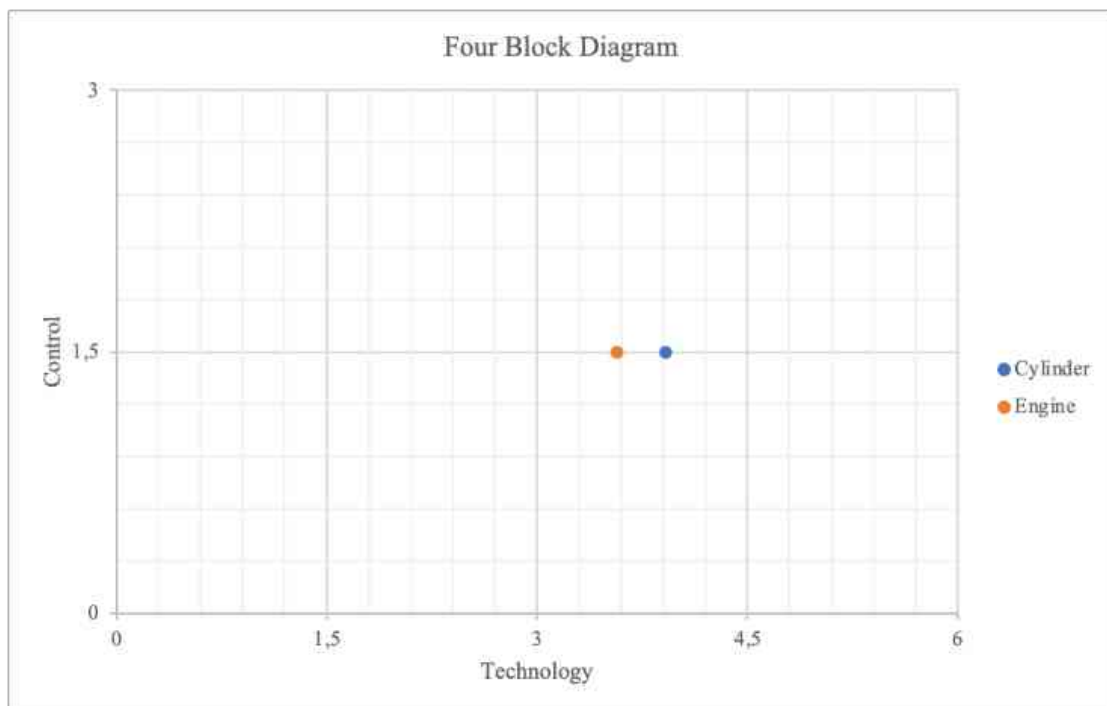


Figure 4.2 Four Block Diagram

Upon examining the Four block diagram depicted in Figure 4.2, it is evident that the control aspect is satisfactory, while the technology aspect is deficient. This implies that enhancements are required in order to achieve optimal control and technological capabilities in both domains.

4.2.3. Cost of poor quality (COPQ) measurement.

In addition to evaluating the initial effectiveness of the Remanufacturing process, an analysis of costs is carried out to consider the inferior quality. This analysis specifically aims to measure the financial consequences of product failures and resulting losses incurred. The corporation is accountable for bearing the expenses associated with internal resources due to product failure, necessitating rework. The Cost of Poor Quality is 10 million IDR for each Cylinder and 25 million IDR for each Engine component. The costs incurred from product failures during the period of January to May 2023 approximately as follows:

No.	Month	Hydraulic Cylinder		Engine		Total COPQ* (IDR)
		Product Failure (Qty)	COPQ* (IDR)	Product Failure (Qty)	COPQ* (IDR)	
1	Jan-23	10	Rp 100.000.000	4	Rp 100.000.000	Rp 200.000.000
2	Feb-23	5	Rp 50.000.000	6	Rp 150.000.000	Rp 200.000.000
3	Mar-23	15	Rp 150.000.000	5	Rp 125.000.000	Rp 275.000.000
4	Apr-23	10	Rp 100.000.000	5	Rp 125.000.000	Rp 225.000.000
5	May-23	10	Rp 100.000.000	5	Rp 125.000.000	Rp 225.000.000
Total		50	Rp 500.000.000	25	Rp 625.000.000	Rp 1.125.000.000

Table 4.3 displays the financial impact of product failures during the period of January to May 2023, totaling 1,125 billion Indonesian Rupiah (IDR).

4.3. Analyse Phase.

The Analyse Phase constitutes the third level of the DMAIC methodology. At this level, the task at hand is to conduct an analysis to determine the underlying causes of product failures. In this scenario, a defect analysis emerges during the Remanufacturing process, as depicted in Figures 4.3.

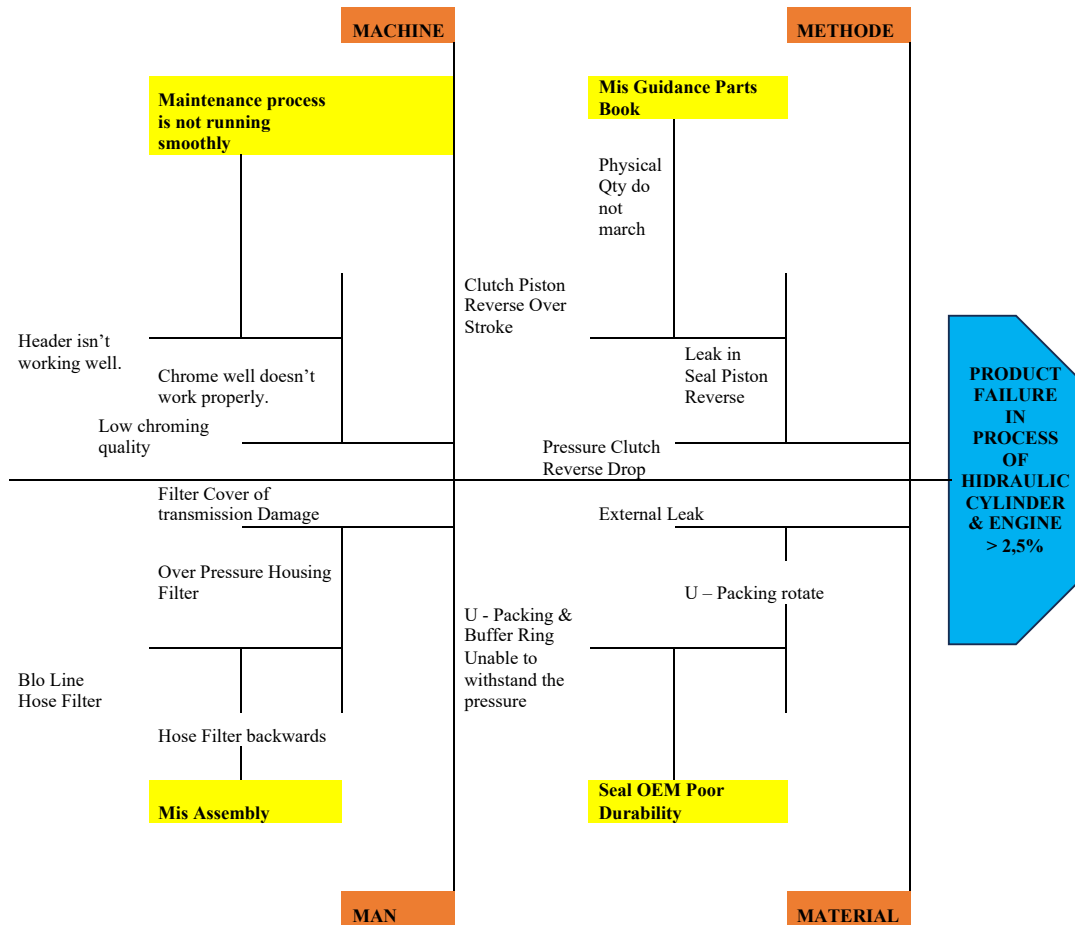


Figure 4.3 Root Cause Analysis of Product Failure

To be able to determine the critical remanufacturing process in this research, a diagnosis must be carried out on the causes of product failure in the process as shown in Figure 4.4.

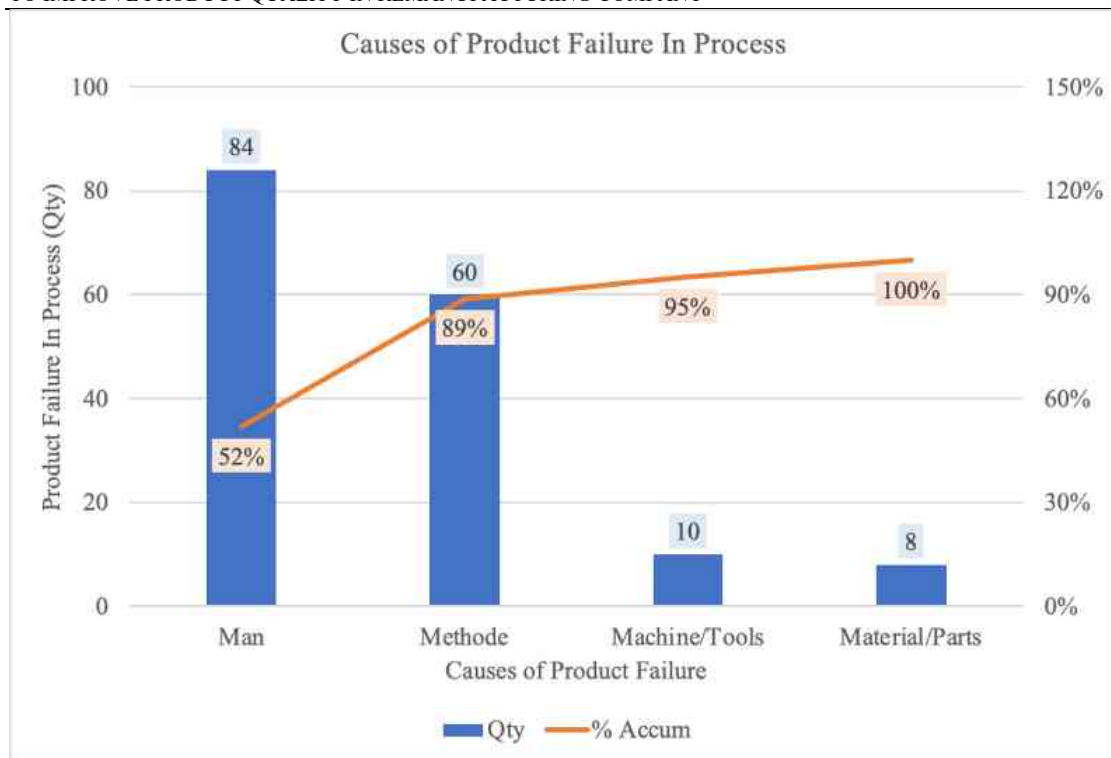


Figure 4.4 Causes of Product Failure in Process 2023

From Figure 4.4 above, the Man & Method factor is the Pareto cause with a contribution of 89% to the total cause of redo in process. Details of the causes of redon in process from the Man & Method factor can be shown in Table 4.4.

Table 4.4 Pareto Root Causes of Product Failure

Causes of Product Failure in Process	Root Causes	Qty	%
Man	Mis Assembly	40	28%
	Mis Performance Test	34	24%
	Mis Inspection	6	4%
	Mis Adjustment	4	3%
Method	Unavailable Procedure	30	21%
	Inappropriate Procedure	15	10%
	Undetailed Procedure	15	10%

Consult the list of Pareto Root Causes listed in Table 4.4. Two The occurrence of defective goods can be attributed to two factors: human error and procedural issues. Specifically, the defects can be categorized as follows: Missed Assembly (28%), Mis performance during Testing (24%), Unavailability of Proper Procedures (21%),

Inappropriate Procedures (10%), and Lack of Detailed Procedures (10%). According to the Pareto product failure idea, 80% of the improvement priority in problem-solving is attributed to a specific set of issues. In this study, the Critical to Quality (CTQ) analysis identified three sorts of issues: Mis Assembly, Mis Performance Test, and Mis Procedure. These three types of issues together account for a cumulative total of 93%. The Assembly and Performance Test method is crucial in this research. The research is cantered on finding strategies to eradicate these imperfections.

From the cause-and-effect diagram, the root cause of Product Failure in the Remanufacturing process & the alternative solution as in Figure 4.5.

Problem	Root Caused	Current	Alternative Solution	Ideal	The Basis of Solution Selected	Decision
Ratio Product Failure in Process > 2,5%	MATERIAL OEM OEM Part Durability, OEM Material Defect, OEM part Unspect	Ratio Problem caused Material OEM is 2%	a. Back to genuine parts	Ratio Problem Material OEM Max. 2.5%	a. Cost : 0	a. Selected
	MATERIAL GENUINE Genuine Material Defect & Genuine Part Durability	Ratio Problem caused Material Genuine is 6%	a. Update Technical from Principle b. Claim to Principle	Ratio Problem Material Genuine Max. 2.5%	a. Cost Review : 0 b. Cost Review : 0	a. Selected b. Selected
	METHODE Unavailable Procedure, Inappropriate Procedure, & Undetailed Procedure	Ratio Problem caused Methode is 37%	a. Review & Revise Quality Document (WI, PSN, QA Sheet, QP)	Ratio Problem Methode Max 2,5%	a. Cost Review : 0	a. Selected
	MAN Mis Assembly, Mis Performance Test, Mis Inspection & Mis Adjusment.	Ratio Problem caused Man is 52%	a. Six Sigma Internal Process Implementation	Ratio Problem Man Max 2,5%	a. Cost Sigma : 0	a. Selected

Figure 4.2 Root Cause and Alternative Solution

4.4. Improve Phase.

The improve step involves identifying and evaluating potential enhancements to address the underlying issues identified during the analyze stage. The transformation plan is implemented through the utilization of a 5W + 1H methodology, which encompasses strategies and corrective measures to each of the variables responsible for the 89% accumulation of product failure attributed to Man & Method. The Assembly and Performance Test process is responsible for the majority of product failures, making it the primary source of the largest product defects.

4.4.1 Review & Revise Quality Document.

In 2022, total Quality Document fulfilment will be 65%, where there are still 16 documents with open status. In 2023, a Quality Document review & revision process

will be carried out for 20 documents to fulfil Quality Document requirements for existing products and new remanufactured products so that the total Quality Document compliance is 100% as shown in Figure 4.6.

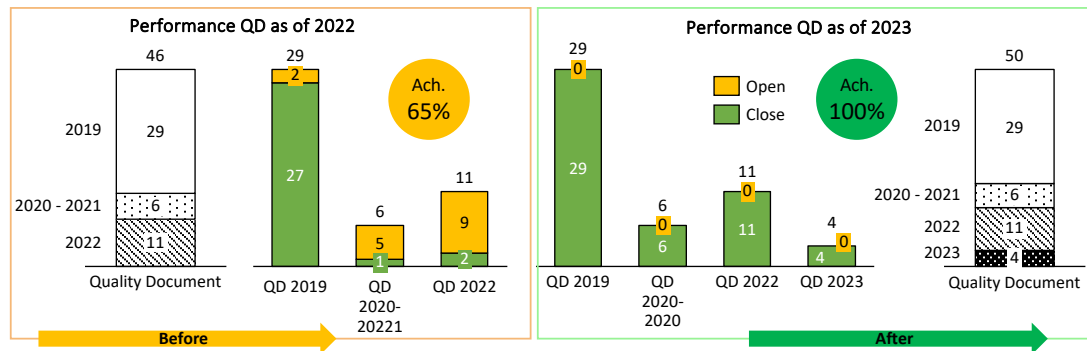


Figure 4.3 Quality Document Fulfillment 2023

4.4.2 Six Sigma Internal Process Implementation.

Six Sigma implementation is carried out through 3 main stages, namely Sigma Workshop, Develop Inspection Form, and Roll Out Implementation process as shown in Table 4.5.

Table 4.5 Timeline of Six Sigma Implementation

No.	Activity	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23
1	Sigma Workshop by MDRM	W1 - W2					
2	Trial Product Engine						
	- Collect Defect Engine	W3 - W4					
	- Develop Inspection Form		W1 - W4				
3	Trial Product Cylinder						
	- Collect Defect Cylinder	W3 - W4					
	- Develop Inspection Form		W1 - W4				
4	Sigma Implementation						
	- Sigma Implementation At RJKT			W1			W4
	- Sigma Implementation At RBPM			W1			W4
	- Sigma Implementation At RBPS			W1			W4
	- Sigma Implementation At RTMK			W1			W4

From the process of diagnosis & identification of critical point assembly and performance test of Hydraulic Cylinder & Engine components, 43 & 53 opportunities were obtained respectively for inspection in the production line as shown in Table 4.6.

Table 4.6 Opportunity Hydraulic Cylinder & Engine

No.	Component	Opportunity of Assembly Process (Qty)	Opportunity of Performance Test Process (Qty)
1.	Hydraulic Cylinder	32	11
2.	Engine	39	14

Each critical point of the assembly process and performance test is arranged in an inspection form that will be used by the Inspector to carry out the inspection and control process to eliminate the potential for product failure as in the example in Figure 4.7.

Figure 4.4 Inspection Form

This stage represents the ultimate stage of the DMAIC process. At this level, the activities involve closely observing and managing the outcomes following the implementation of enhancements. The process capability or sigma level is assessed and categorized into four segments. Cost of poor quality (COPQ) is subsequently determined to evaluate the effectiveness of the improvements. Additionally, new processes are standardized to prevent future occurrences of similar product failures.

4.5.1. Measurement of process capability/sigma level (post-improvement).

The remanufacturing and quality control department collected data during the initial week of August 2023 until the last week of November 2023. During this period, a total of 720 Hydraulic Cylinder & Engine components were produced. The process capability/sigma level calculation is displayed in Table 4.7.

Table 4.7 Sigma Calculation August to November 2023

Product	Assembly				
	Production (Qty)	Defect (Qty)	Opportunity (Qty)	Total Opportunity (Qty)	DPMO
Cylinder	620	8	32	19.840	403
Engine	100	4	39	3.900	1.026

Product	Performance Test				
	Production (Qty)	Defect (Qty)	Opportunity (Qty)	Total Opportunity (Qty)	DPMO
Cylinder	620	8	11	6.820	1.173
Engine	100	4	14	1.400	2.857

Product	Assembly	Performance Test	Total DPMO	Table Z	Sigma Provision	Total Sigma
	DPMO	DPMO				
Cylinder	403	1.173	1.576	3,01	1,5	4,51
Engine	1.026	2.857	3.883	2,72	1,5	4,22

4,36

Table 4.7 demonstrates that the assembly and performance test process has improved to a capability of 4.36 sigmas, with a DPMO of 5,459. This is a significant improvement compared to the previous conditions, which had a capability of 3.74 sigmas and a DPMO of 20,151.

4.5.2. Four block diagrams (post improvement).

By utilizing the data presented in Table 4.7 and employing the identical calculation method used during the measure stage, the sigma level before implementing

improvements (4.36) can be visually represented in the four-block pattern depicted in Figure 4.8.

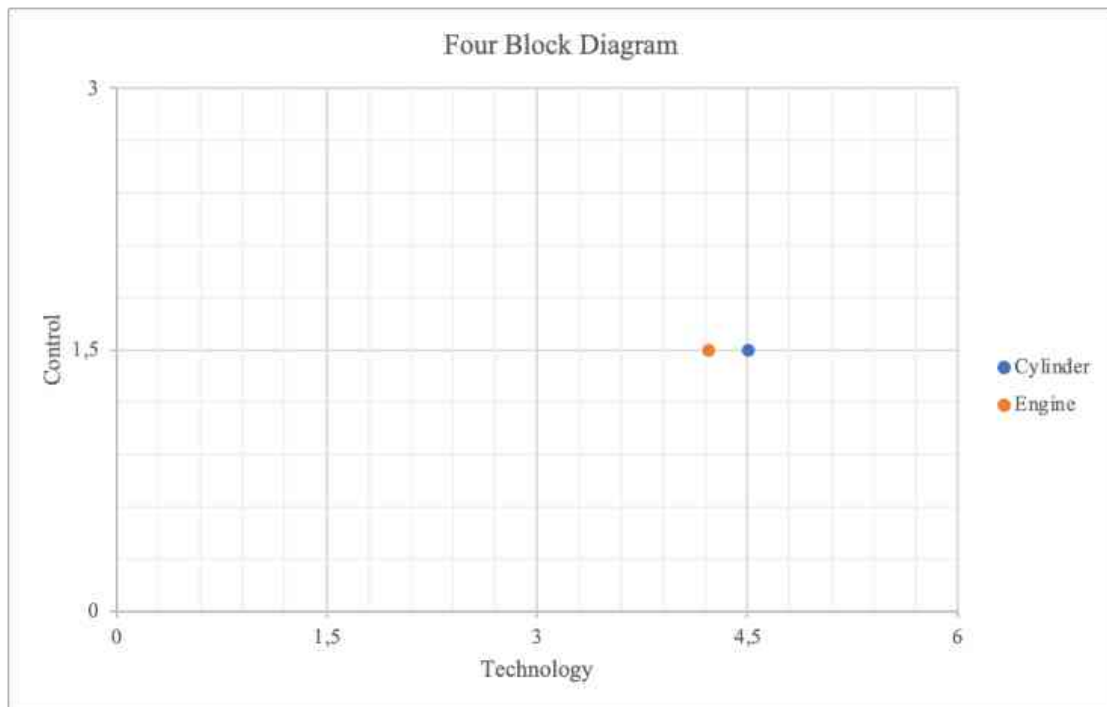


Figure 4.5 Four Block Diagram

4.5.3. Cost of poor quality (COPQ) post improvement.

Similar to the measurement phase, the computation for costs of poor quality (COPQ) involves quantifying the financial losses incurred by the company due to product failures. The cost of poor quality is 10 million IDR for each cylinder and 25 million IDR for each engine component. The calculations for the Cost of Poor Quality (COPQ) following the improvement can be observed in Table 4.8.

Table 4.8 Cost of Poor Quality (COPQ)

No.	Month	Hydraulic Cylinder		Engine		Total COPQ* (IDR)
		Product Failure (Qty)	COPQ* (IDR)	Product Failure (Qty)	COPQ* (IDR)	
1	Aug-23	5	Rp 50.000.000	3	Rp 75.000.000	Rp 125.000.000
2	Sep-23	4	Rp 40.000.000	2	Rp 50.000.000	Rp 90.000.000
3	Oct-23	4	Rp 40.000.000	2	Rp 50.000.000	Rp 90.000.000
4	Nov-23	3	Rp 30.000.000	1	Rp 25.000.000	Rp 55.000.000
Total		16	Rp 160.000.000	8	Rp 200.000.000	Rp 360.000.000

Table 4.8 The statement implies that the company's loss resulting from product failure, after implementing improvements, has fallen to 360 million IDR from the previous amount of 765 million IDR, which is equivalent to a 68% reduction.

Overall, the implementation of Six Sigma has had a positive impact, namely reducing Failure in Process (FIP), improving Sigma levels, and reducing the Cost of Poor Quality (COPQ) as seen in table 4.9.

Table Error! No text of specified style in document.9 Comparison of Before and After Six Sigma Implementation

Product	FIP Before			FIP After		
	Production (Qty)	FIP (Qty)	% FIP	Production (Qty)	FIP (Qty)	% FIP
Cylinder	775	50	6%	620	8	1%
Engine	125	25	20%	100	4	4%
Grand Total	900	75	8%	720	12	2%

Product	Total Sigma Before	Total Sigma After
Cylinder	3,92	4,51
Engine	3,57	4,22
Grand Total	3,75	4,365

Product	COPQ Before	COPQ After
Cylinder	Rp 500.000.000	Rp 160.000.000
Engine	Rp 625.000.000	Rp 200.000.000
Grand Total	Rp 1.125.000.000	Rp 360.000.000

4.5.4. Standardization

a. Standard Operational Procedure (SOP): In order to prevent the occurrence of similar product failures, specifically Mis Assembly and Mis Performance Test, during the remanufacturing process, it is important to share the results of improvement with all relevant levels and establish fresh guidelines within the form of Standards Operational Procedure (SOP) for Assembly and Performance Test processes, as illustrated in Figure 4.9.

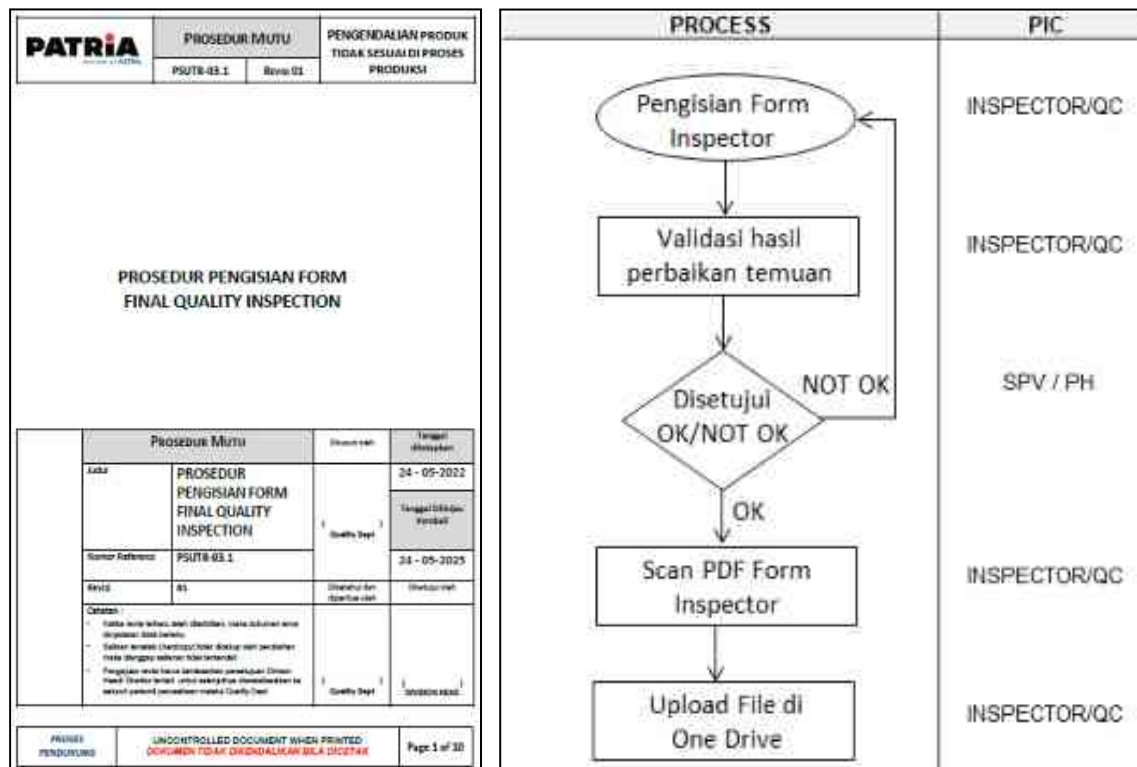


Figure 4.6 Standard Operating Procedure of Quality Inspection Process

Several provisions relating to the implementation of Quality Inspection SOPs include the following:

1. Every time there are findings in the inspection report, a PTPP Form must be made Max 1 x 24 Hours.
2. Scan of the Inspector Form and PTPP pdf are reviewed weekly at the Head Office.
3. Calculation of Sigma values can be done every week.
4. Calculation of final Sigma values is done at the end month.

b. Daily Management & Monthly Review: To ensure that there is sustainable improvement in the quality of remanufactured products, a monitoring & review process is periodically carried out with the following conditions:

- i. Daily Management: Every day before work starts, 15 to 30 minutes to discuss findings & PICA implementation of quality inspection.
- ii. Monthly Quality Meeting: Once a month for 1 to 2 hours to discuss progress updates related to the implementation of quality inspection, product failure issues in process and product failure issues in the field.

4.5.5. Digital Quality Dashboard.

To ensure that there is a consistent and real-time monitoring - review process, a Digital Quality Dashboard has been prepared which includes Product Failure in Field (FIF), Product Failure in Process (FIP), Cost of Product Failure, and Six Sigma Level as presented in Figure 4.10.



Figure 4.10 Digital Quality Dashboard

- Product Failure in Field.

Product failure in the field refers to customer complaints received by PT United Tractors Pandu Engineering. On the product failure in the field line chart, there are two lines: ETR ratio and failure ratio.

a) ETR Ratio

ETR ratio is derived from the data of the total customer complaints received and still undergoing analysis to determine whether the product claims are accepted or rejected, divided by the total number of product deliveries.

Example: In January, there were 12 customer complaints and a total delivery of 561 components. Therefore, the ETR ratio for January is:

$$\%ETR \text{ Ratio} = \frac{\text{Total customer complaint}}{\text{Total Delivery}} \times 100\% \quad (4.8)$$

$$\%ETR \text{ Ratio} = \frac{12}{561} \times 100\% = 2.13\% \quad (4.9)$$

b) Failure Ratio

The failure ratio is obtained from the data of the total customer complaints with accepted status, divided by the total number of product deliveries.

Example: In January, there were 12 customer complaints, out of which 9 complaints had an accepted status, and the total delivery was 561 components.

Therefore, the Failure ratio for January is:

$$\%Failure \text{ ratio} = \frac{\text{Total customer complaint accept}}{\text{Total Delivery}} \times 100\% \quad (4.10)$$

$$\%Failure \text{ ratio} = \frac{9}{561} \times 100\% = 1.6\% \quad (4.11)$$

- Product failure in process

Product failure in process refers to product failures that occur during the remanufacturing process and require additional costs in the form of spare part purchases. The data used for product failure in process includes the number of failures that occur in the production process and the total production of components. To calculate failure in process as shown in the graph, the formula used is:

$$\%Failure = \frac{\text{Total failure in process}}{\text{Total Production}} \times 100\% \quad (4.12)$$

Example: In January, there were 2 failures in process occurrences during the production process, and the total production for January was 717.

Therefore, the failure in process percentage for January is:

$$\%Failure = \frac{2}{717} \times 100\% = 0.2\% \quad (4.13)$$

- Six Sigma.

Six Sigma is a quality management method aimed at improving business process efficiency and reducing variability by identifying and eliminating defects or errors. On the sigma chart, there are four lines representing internal process sigma, product failure sigma, and target sigma.

- Cost Failure in Field (FIF)

Cost FIF represents the expenses incurred to address product failures in the field. The data used in this graph includes the costs associated with resolving product failures in the field and total revenue. To calculate Cost Failure in Field, the formula used in the graph is as follows:

$$\%Cost\ FIF = \frac{Cost\ incurred\ for\ product\ failure\ in\ field}{Total\ revenue} \times 100\% \quad (4.14)$$

Example: In January, there were 2 product failures in the field with a total cost incurred to address these failures amounting to Rp 19,263,000. The total revenue for January was Rp 55,000,000. Therefore, the cost failure in field ratio for January is:

$$\%Cost\ Failure\ As\ Of\ Januari = \frac{Rp\ 19.263.000}{Rp\ 55.000.000.000} \times 100\% = 0.035\% \quad (4.15)$$