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The Impact of Increasing Sigma Value on the Performance of the Weapon Production Line at PT. X

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Abstract

PT. X is one of the companies that produces the Main Armament System (Alutsista) used by the Indonesian National Army. In an effort to meet the production needs of Assault rifle weapons, PT. X must meet the quality standards set by the Ministry of Defense to support the operational tasks of the Indonesian National Army. This study aims to improve the performance of the weapon production line by measuring and evaluating the amount of sigma value in long-barreled weapons. The method used in this research is DMAIC (Define, Measure, Analyze, Improve, and Control), which is a structured approach to quality improvement. This method is used to address problems that occur on the weapon production line and analyze improvements that can be made to improve production performance. The steps recommended in this study include using the Critical to Quality method to identify the causes of problems that occur in weapon production. Furthermore, the Cause and Effect method is used to rank the most significant causes of problems based on the scores obtained. The 5W+1H method is also used to formulate appropriate improvement proposals based on the ranking results from the Cause and Effect Matrix. Thus, it is expected that an effective improvement proposal can be found to improve the performance of PT. X weapon production line.

Keywords: Alusista, Defence Industry, DMAIC, Quality Performance, Six Sigma.

1. Introduction

PT. X is a manufacturing company for the production of weapons, ammunition and commercial explosives in Indonesia, judging from its business continuity, this company is an international weapons manufacturing company.In making defense equipment products that have quality standards in accordance with the requests of the Ministry of Defense, one of which is the Assault refle Weapon product, PT. X must make improvements to long barrel weapon products which are considered to have a number of defective components in each production.

Throughout 2022 Assault rifle -Var was produced as many as 36741 units in the production process the total number of rejects reached 354 with a total number of rework 189 this shows that the percentage of rejects and rework reached 0.97%, and 0.51% of 36741 units produced with total reject and rework costs of IDR 284,010,295.00 and IDR 41,766,165.00 respectively. The calculation of the DPMO value and the sigma level carried out the goal is to find out how many defects per million production and carried out as an effort for continuous improvement towards perfection. Quality improvement carried out on the weapon production line is carried out by using how to calculate the amount of sigma obtained and used as a basis for data processing on the components of the assault refle weapon unit.

Six Sigma is a structured tool or method used to improve processes and develop new products based on statistics and scientific methods to reduce defects according to consumer needs. It was first introduced at Motorola in 1979, focusing on quality issues and referring to six standard deviations. From Total Quality Management (TQM), Six Sigma has the concept that every member should be responsible for the quality of goods and services produced. Other concepts that can be traced from TQM are the focus on customer satisfaction, significant investment in statistical education and training, root cause analysis and other problem-solving methods. The basic concept of Six Sigma is to improve quality towards zero failure rate which means that Six Sigma efforts are to reduce the occurrence of defects in a production process with the ultimate goal of creating Zero Defect. Defect itself is defined as a mismatch to a predetermined specification.

Six Sigma levels are often linked to process capability, which is calculated in defects per million opportunities. In identifying and anticipating errors before they occur. In the process of assessing the amount of sigma value, there are references that have been standardized internationally. The following is the magnitude of the sigma value What is the level of Sigma achievement based on DPMO can be seen in table 1:

Table 1: Six Sigma Table

Sigma Level	Defects per Million Opportunities	Percentage Yield
1σ	691,462	31
2σ	308,537	69
3σ	66,807	93.3
4σ	6,210	99.38
5σ	233	99.977
6σ	3.4	99.99966

Source: Vincent Gasperz

The process carried out in six sigma is the DMAIC method. DMAIC is a management process developed by Six Sigma. It is a mnemonic of Define, Measure, Analyze, Improve and Control. DMAIC is used to analyze existing or new processes and reduce variability and errors. The DMAIC process includes five main stages, namely: Define, Measure, Analyze, Improve, and Control. Each stage includes various techniques and tools that help achieve process improvement goals. Six Sigma and DMAIC are management methods that aim to achieve high quality and reduce the number of errors. Six Sigma incorporates various statistical techniques to identify and anticipate errors before they occur. DMAIC is a management process developed by Six Sigma to analyze existing or new processes and reduce variability and errors.

The use of the six sigma method in the improvement of the weapon production line that brings together business and business opportunities to generate new knowledge in the process of solving problems regarding the quality of products, services, and processes. six sigma is controlled by facts, data, and statistical analysis to become a strong underlying basis for managing a business or improving and replanting a business. In its utilization, six sigma is cost reduction, product defect reduction, productivity improvement, production and service development to see market share growth. In the problem solving process, six sigma uses a procedure, namely DMAIC (define, measure, analyze, improve and control). Where the main goal is to minimize defects from existing processes for example to 3.4 defects per million activities or opportunities, thereby improving product quality and business profits to ultimately lead to business excellence. Furthermore, measurements are made of the value of defects that have the most influence on the production process with the cause and effect priority score approach. The cause and effect priority score is carried out to determine the most influential defect value in the long-barreled weapon production process.

From the existence of six sigma, it is hoped that the company can reduce the level of production defects and improve the quality of production of long-barreled weapons so that it has competitiveness in the military world. Therefore, this research will examine the application of six sigma to confirm, forming a hypothesis that this methodology meets the requirements for looking at weapon production defects at PT Pindad where later the method can be used to increase the sigma value of PT Pindad's weapon production line performance. This research is also an argument to promote the DMAIC methodology as an efficient organized action to see the scale of defects in weapon products until finally found solutions and suggestions to overcome problems in production defects.

2. Methods

This research process uses a qualitative approach with the DMAIC method, which consists of the initial stages, data collection using Check Sheet, primary and secondary data analysis, analysis and discussion, and conclusions and suggestions.

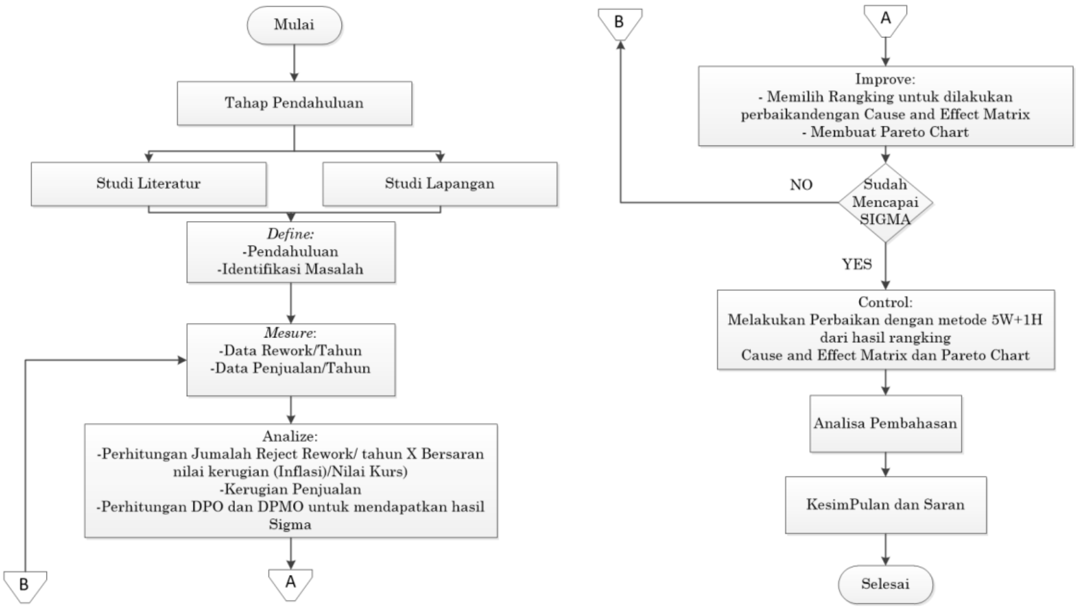

Figure 1: Flowchart for Research Design

Six sigma is referred to as a measurement system because it uses Defects per Million Opportunities (DPMO) to reduce variation from the average (mean) of a process or procedure, which corresponds to the meaning of sigma, which is distribution or spread (variation).

Rework / reject is taken from the number of long-barreled weapon units that experience rework / reject on certain components. The amount of loss value is assumed from the purchase price of raw materials for making long barrels and the exchange rate which determines the decrease or increase in the price of long barrel components with the assumption that the raw materials supporting the manufacture of long barrels are purchased from abroad. The calculation of losses can be seen in the following formula:

$$\text{Loss calcuation} = \text{Rework/Year} \times \text{Loss Rate (Inflasion)} \times \text{(Exchange Rate)} \quad (1)$$

(Source: PT. X – Weapon Division Engineering Fungsion)

The way to determine DPMO :
DPMO = (Number Of Defect Unit)/(Number of Inspection Unit x CTQ) x 1.000.000 (2)

3. Result and Discussion

3.1. Define

The results of the study produced primary data on Company General Information, types of defects that occur and secondary data containing the types of products produced, the number of products produced in a certain period of time, the number of Riject and Rework products produced in that period of time, and the costs of Riject and Rework.

Product defects in this study are divided into 3 types including Fabrication, Testing, Visual defects. Fabrication defects can be identified if they meet the following criteria: Inner Thread / Outer Thread Defect, Shape Defect, Component / Material Measurement Error, Design Error / Inappropriate Shape, Hole not Centered, Hole not Centered. Testing defects can be identified if Reliability and Durability Do Not Meet Test Standards, There are Damaged Products or Components, Products Do Not Comply with Test Standards. Visual defects can be identified if the component shape does not match the drawing / dimensions, component / product cracks, incomplete constituent components, uneven color.

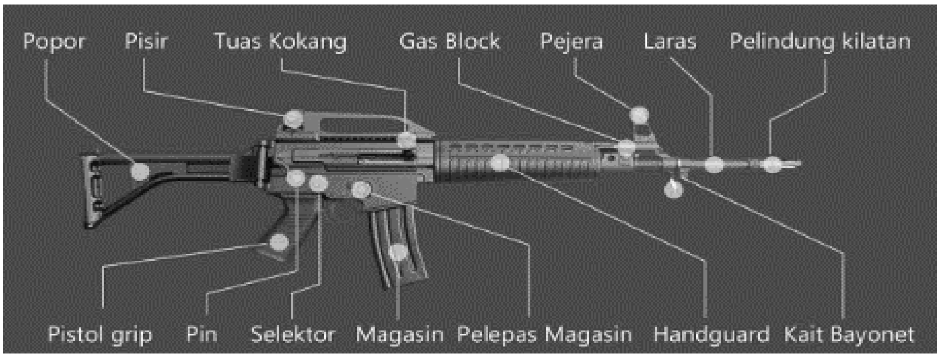

Figure 2: Assault Rifle Components
Source: PT. X

The assumption of rework costs for components in the long-barreled weapon unit is IDR 220,985, - and the amount of reject costs for components in the long-barreled weapon unit is: IDR 800,029,-. The increase in the amount of inflation is assumed to be 3% for the value of rejects and rework, this is obtained from an increase in world inflation and considering that production costs are also affected by Cost living Adjustment.

4. Mesure

Table 2: Tabulation of the 2022 Disability Check Sheet

No	Month	Production Assault Rifle -Var	Total Number of Reject Production	Defect type			Total Number of Production Reworks	Total Reject & Rework	Quantity Good Products
				Fabrication Defects	Test Defects	Visual Defects			
1	January	3063	30	25	1	4	15	45	3018
2	February	3086	28	20	4	4	20	48	3038
3	March	3099	35	28	5	2	19	54	3045
4	April	3026	35	29	1	5	13	48	2978
5	May	3002	30	22	5	3	14	44	2958
6	June	3055	27	23	2	2	18	45	3010
7	July	3084	23	21	1	1	11	34	3050
8	Agusts	3097	32	26	3	3	10	42	3055
9	September	3061	26	22	1	3	16	42	3019

10	October	3048	30	22	3	5	19	49	2999
11	November	3049	27	23	2	2	17	44	3005
12	December	3071	31	24	3	2	17	49	3023
			354				189	544	36198

Source : PT. X (2022)

The calculation of the DPMO value and the sigma level carried out the goal is to find out how many defects per million production and carried out as an effort for continuous improvement towards perfection.

Throughout 2022 Assault rifle -Var was produced as many as 36741 units in the production process the total number of rejects reached 354 with a total number of rework 189 this shows that the percentage of rejects and rework reached 0.97%, and 0.51% of 36741 units produced with total reject and rework costs of IDR 284,010,295.00 and IDR 41,766,165.00 respectively.

To calculate the DPMO value and sigma level, the data used is the defective product data of the Assault Rifle- Var in 2022. The defective product data of Assault Rifle -Var Products which are CTQs are as follows:

Table 3: Total Critical to Quality

Defect Type	**Total**	**Defect Type**	**Total**
Popor	26	Selector	24
Pisir	25	Magasin	31
Tuas Kokang	26	Pelepas Magasin	25
Gas Block	35	Hand Guard	25
Pejera	27	Kait Bayonet	33
Laras	28	Defects Quantity	354
Pistol Grip	20	Production Quantity	36741
Pin	30		

5. Analize

Loss calcuation = Rework/Year x Loss Rate (Inflasion) x (Exchange Rate) (1)
(Source: PT X – Weapon Division Engineering Fungsion)

$$= \text{IDR } 41.766.165{,}00\ x\ (1{,}87\ x\ 15053{,}11)$$

$$= \text{IDR } 41.766.165{,}00\ x\ 29396{,}7927$$

$$= \text{IDR } 1.175.688.964.163{,}29 \text{ Loss}$$

The way to determine DPMO :
DPMO = (Number Of Defect Unit)/(Number of Inspection Unit x CTQ) x 1.000.000 (2)

$$\text{DPMO} = \frac{354}{36741\ x\ 13}\ x\ 1.000.000$$

$$\text{DPMO} = 741{,}1548$$

While the sigma level is obtained from the calculation of the sigma value with the help of a sigma calculator as follows:

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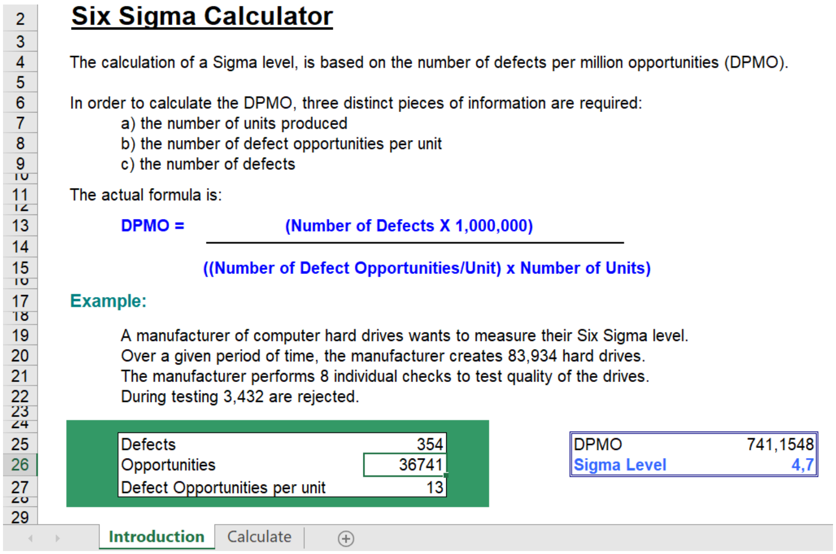

Figure 3: Calculation of Sigma Level with Excel

Based on the calculation of the loss, the number obtained is IDR 1,175,688,964,163.29 Loss while the DPMO value obtained above, the long-barreled weapon production process has a sigma level of 4.7 and a DPMO of 741.1548 which means a process that has a probability of defects of 741.1548 pieces in one million products, so, if the company is at a sigma level of 4.7, it means that in the process we call it has a chance to defect / make mistakes as much as 741.1548 out of one million possibilities.

The Cause and Effect Matrix is usually called the C&E Matrix. It provides a way to assess the mapping of input factor X and output factor Y. With this relationship, the contribution value can be measured easily to find the most influential factor. The method used in the C&E Matrix is ranking and decision making. This process starts from factor input X to factor output Y. The first thing to understand is consumer demands. What is actually needed by consumers related to the problem being addressed. The following is a display of the C&E Matrix obtained from the root cause analysis of defective products:

6. Improve

Table 4: Cause and Effect Matrix

	CTQ						Total	Range
Weighted by Importance	**8**		**10**		**7**			
Cause	Fabrication Defects		Test Defects		Visual Defects			
Inner Thread / Outer Thread Defects	9	72	9	90	1	7	169	6
Shape Defects	9	72	9	90	9	63	225	1
Component / Material Measurement Error	9	72	9	90	3	21	183	3
Design Error / Inappropriate Shape	3	24	3	30	9	63	117	9
Material not according to specifications	9	72	3	30	0	0	102	12
Hole not centered	9	72	9	90	1	7	169	6
Hole is not centered	9	72	9	90	3	21	183	3
Reliability and Durability Does Not Meet Test Standards	3	24	9	90	0	0	114	11
There are damaged products or components	9	72	9	90	9	63	225	1
Products do not comply with test standards	9	72	9	90	3	21	183	3
Component shape does not match the drawing / dimensions	9	72	3	30	9	63	165	8
Component / Product Cracks	3	24	3	30	9	63	117	9
Incomplete constituent components	0	0	3	30	9	63	93	13
uneven color	0	0	0	0	9	63	63	14
Inner Thread / Outer Thread Defects	9	72	9	90	1	7	169	6

In Table 4, there are three types of defects with priority scores ranging from 1 to 10, where 1 is the least important value and 10 is the most important value. The correlation weights between defect causes and outcomes are also determined into four categories, namely 0 (no relationship), 1 (little relationship), 3 (average) and 9 (strong relationship). The C&E Matrix results are then sorted based on the highest total after the calculation process between CTQ and Cause.

Table 5: Selected Scores

Notasi	*Cause*	Total	Range
B	Defects	225	1
I	There are damaged products or components	225	1
C	Component / Material Measurement Error	183	3
G	Hole is not centered	183	3
J	The product does not comply with the test standard	183	3
A	Inner Thread / Outer Thread Defects	169	6
F	Hole is not centered	169	6
K	Component shape does not match the drawing / dimensions	165	8
D	Design error / shape does not match	117	9
L	Component / Product Cracks	117	9
H	Reliability and Durability Does Not Meet Test Standards	114	11
E	Material Does Not Match Specifications	102	12
M	Incomplete constituent components	93	13
N	uneven color	63	15
B	Shape Defects	225	1

After sorting the total values from highest to lowest, it can be seen which priorities to propose. To make it easier to select the causes that need to be improved and given proposals, do a Pareto diagram.

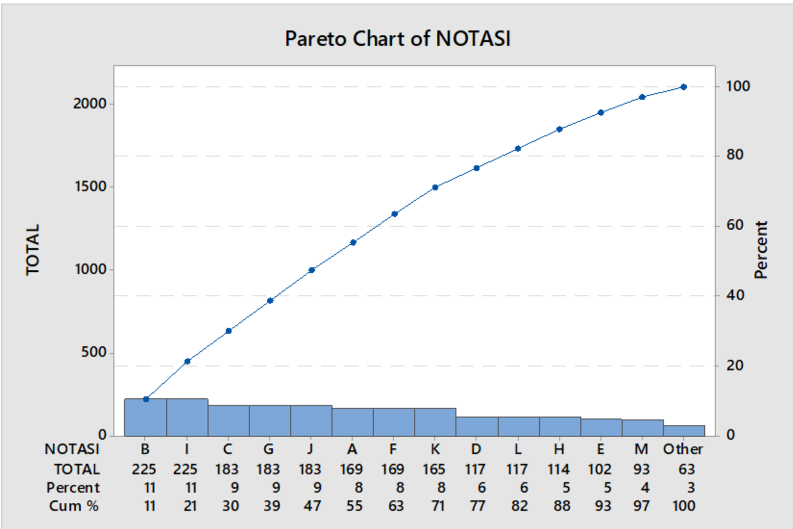

Figure 4: Pareto Chart from Cause and Effect Matrix

From the Pareto Diagram above, it can be seen that the types of defects with the largest percentage, namely A-O, are Deformed and There are Damaged Products or Components. The cumulative percentage for these types of defects reaches 72%. This value is in accordance with the 80-20 Pareto principle, where 80% of defective products are caused by 20% of defects.

After the causes of process failure are analyzed, the root cause of the problem is sought and prioritized, then an improvement proposal is made to the process which is first made in the 5W1H method table. Proposed improvements that are prioritized are only made to the causes of process failure that have the notation A-O. Recommendations or suggestions for improvements to product defects using six sigma, namely conducting more routine inspections, controlling and checking tools and machines when doing work, training new employees for min 2 weeks, making inspection SOPs or work procedures and structured and detailed quality, scheduling routine machine maintenance, checking machines when starting work, adding other production operator employees whose workload is not too large to equalize the workload of each division.

7. Control

Table 6: Improvement Plan with 5W+1H

Root of the Problem (What)	Why	Where	When	How to fix	Who is doing
Defects	Lack of operator accuracy during fabrication	Component/Product Fabrication Process Place	During the Fabrication Process	1. Safety briefing before and after work 2. 2. Training related to autoCAD / technical drawings is conducted. 3. Training on machines used / operator certification	1. Operations Manager 2. Machine Operator
Defective Products or Components	Storage of finished products / components is not in accordance with the SOP	Where Component/Product Fabrication Process	During the fabrication process	1. Compilation of complete SOPs related to the storage of components/finished products 2. Create component warehouse and finished goods warehouse 3. Develop a logistics strategy with the Pareto ABC warehousing model	Company Management
Component/Material Measurement Error	The measuring and test equipment used is on average over 20 years old	Where Component/Product Fabrication Process	During the Fabrication Process	1. Supervision of operators is carried out 2. Conducted training for operators who use machines 3. Invest in measuring and testing equipment	1. Production Manager 2. Production Operator 3. Company Management
Product does not comply with test standards	1. Technical defects occur in the finished product 2. The measuring and test equipment used is on average over 20 years old 3. Materials are not in accordance with core specifications	Product Quality Test Site	During Product Quality Test	1. Invested in the machines used 2. Conducted training for machine operators 3. Search for substitute materials in accordance with product specifications	1. Company Management 2. Production Operator 3. Supply Chain Division

Root of the Problem (What)	Why	Where	When	How to fix	Who is doing
Inner Thread / Outer Thread Defects	1. Measuring and testing instruments used are on average over 20 years old. 2. Lack of operator accuracy in the fabrication process	Where Component / Product Fabrication Process	During Fabrication Process	Invest in measuring instruments and product quality tests	Company Management
Hole is not centered	1. The measuring and test equipment used is on average over 20 years old 2. Lack of operator accuracy in the fabrication process	Component / Product Fabrication Process Place	During Fabrication Process	1. Invest in measuring instruments and product quality tests 2. Conducted training for operators	1. Company Management 2. Production Operator
Component shape does not match the drawing / dimensions	1. Lack of operator accuracy during component manufacturing 2. There is a different design	Component / Product Fabrication Process Place	During Fabrication Process	Certification and training of operators who perform product assembling is carried out	Production Operator
Design Error/Inappropriate Shape	1. The design form given is too complicated 2. Lack of operator accuracy	Engineering Design Innovation Division	During Fabrication Process	Certification and training of operators who perform product assembling is carried out	Production Operator
Component / Product Cracks	1. Lack of operator accuracy during fabrication 2. Limited storage space 3. Placement of materials does not use material handling	Component / Product Fabrication Site	During the Fabrication Process	1. Certification and training of operators who perform product assembling are carried out 2. Establish a finished product warehouse and parts warehouse 3. Use material handling when laying out components and finished products	1. Production Operator 2. Company Management
Reliability and Durability Does Not Meet Test Standards	1. Materials used are not in accordance with specifications 2. Lack of accuracy of test operators	Product Quality Test Site	During Product Quality Test	1. Searching for substitute materials with the required specification conformity 2. Certify operators who perform quality testing of products	1. Supply Chain Division 2. Production Operator
Incomplete constituent components	Lack of operator accuracy during the product assembly process	Component / Product Fabrication Process Place	During Fabrication Process	There is a re-check conducted by Quality inspectors	Quality Inspector
Material Does Not Match Specifications	Scarcity of component support materials	Supply Chain Division	During the material procurement process	1. Use e-procurement in registering component provider vendors 2. Searching for substitute materials that meet specifications	Supply Chain Division
Uneven Color	1. Lack of operator accuracy when performing the painting process 2. Component shape is very detailed and detailed	Product / Component Painting Place	During the process of coating parts with paint	1. Conduct material painting certification against 2. Invest in automation-based painting machines	1. Production Operator 2. Company Management

8. Conclusion

1. There are three types of defects, namely Fabrication defects, Testing defects, Visual defects as for the identification that has been done is the cause of this defect is 80% of the ranking of defects that are prioritized for repair.

2. The results of the calculation of the DPMO value obtained a value of 741.1548 and the results of the sigma level of 4.7. This level is still far away when compared to world-class companies that reach 6 sigma, therefore the company must continue to make improvements in order to improve the quality of its products.
3. The results of the calculation of Rework / reject losses are taken from the number of long-barreled weapon units that experience rework / reject on certain components. For the amount of loss value, it is assumed from the purchase price of raw materials for making long barrels and the exchange rate which determines the decrease or increase in the price of long barrel components with the assumption that the raw materials supporting the manufacture of long barrels are purchased from abroad, namely and obtained a loss value of IDR 1,227,791,294,379.00 Losses.
4. Recommendations or suggestions for improvements to product defects using six sigma, namely conducting more routine inspections, controlling and checking tools and machines when doing work, training new employees for min 2 weeks, making inspection SOPs or work procedures and structured and detailed quality, scheduling routine machine maintenance, checking machines when starting work, adding other production operator employees whose workload is not too large to equalize the workload of each division.

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