Quality Control of Welding Defect at PT XYZ Using the Six Sigma Method by Integrating the DMAIC Method

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ABSTRACT

This study aims to analyze and reduce welding defects at PT XYZ using the Six Sigma method integrated with the DMAIC (Define, Measure, Analyze, Improve, Control) approach and the Seven Tools of Quality Control. Welding defects are a critical issue in manufacturing industries as they increase rework and scrap costs, reduce production efficiency, and negatively impact product quality and customer satisfaction. This research adopts a quantitative case study approach. Primary data were collected through direct observation, operator interviews, and defect recording using check sheets, while secondary data were obtained from production reports and company operational documents. In the Measure phase, the analysis showed an average Defects Per Million Opportunities (DPMO) value of 25,744.185 with a sigma level of 3.44, indicating that the process is relatively stable but still requires improvement. The Analyze phase identified the root causes of defects using fishbone diagrams, revealing that the main contributing factors include human, machine, method, and material aspects. Furthermore, Risk Priority Number (RPN) analysis indicated that incorrect welding parameter settings, worn contact tips, malfunctioning jig clamps, and inaccurate teaching points are the most critical causes. Improvement strategies were developed using the 5W+1H approach, including parameter standardization, operator training, routine maintenance, and stricter process monitoring. The implementation of Six Sigma is expected to reduce defect rates, improve process capability, and support continuous quality improvement at PT XYZ.

Keywords: Six Sigma, Quality Control, DMAIC, Welding Defects, DPMO

INTRODUCTION

The manufacturing industry is required to produce products with high quality, efficient costs, and optimal production time. In an increasingly competitive global environment, companies are not only required to improve productivity but also to ensure that every product produced meets established quality standards. Failure to maintain quality can result in increased rework and scrap costs, delayed deliveries, and decreased customer trust.

One of the critical processes in the manufacturing industry, especially in companies engaged in metal fabrication and construction, is the welding process. The quality of welding results greatly determines the strength, durability, and safety of the final product. Welding defects such as porosity, undercut, incomplete fusion, cracks, and excessive spatter can reduce product quality and potentially cause structural failure risks. Therefore, quality control in the welding process is a very important aspect of the company's quality management system.

The Six Sigma approach is one of the systematic and data-based quality control methods. In its implementation, the DMAIC (Define, Measure, Analyze, Improve, Control) cycle is used as a comprehensive problem-solving framework.

PT XYZ, as a manufacturing company engaged in the production of welding-based components, faces the problem of a high welding defect rate in recent periods. Defect levels exceeding company standards have increased production costs due to rework and scrap and have the potential to disrupt delivery timeliness to customers. This problem indicates that a comprehensive analysis is needed to identify the factors causing defects and determine appropriate corrective actions.

Based on this background, this study aims to analyze the types and causes of welding defects at PT XYZ using the Six Sigma method with the DMAIC approach and to provide improvement recommendations to reduce defect levels and increase production process stability. It is expected that the results of this study will contribute to continuous improvement efforts in the manufacturing industry.

LITERATURE REVIEW

Quality control is a fundamental aspect of modern industrial operations, aiming to ensure that products meet predetermined standards and customer expectations. According to W. Edwards Deming, quality should be built into the process rather than inspected at the end of production. Similarly, Joseph M. Juran defines quality as “fitness for use,” emphasizing the ability of a product to satisfy customer needs. Philip B. Crosby further states that quality means conformance to requirements, highlighting the importance of zero defects. In addition, Montgomery explains that quality control involves the application of statistical techniques to monitor and control production processes.

In the industrial context, quality control plays a crucial role in improving operational efficiency, reducing defect rates, and enhancing customer satisfaction. Ineffective quality control may lead to increased production costs, rework, and loss of competitiveness. Therefore, many manufacturing industries adopt data-driven approaches such as Six Sigma to systematically improve process performance and reduce process variability.

Six Sigma is a quality management approach aimed at improving process performance. According to Mikel Harry and Richard Schroeder (2010), Six Sigma is a data-driven approach aimed at reducing process variation and achieving a defect rate as low as 3.4 defects per one million opportunities (Defects Per Million Opportunities/DPMO), which corresponds to a six sigma performance level. Based on this concept, Six Sigma emphasizes improving process capability through strict statistical control.

DMAIC is a structured improvement cycle in Six Sigma used to improve existing processes. DMAIC also ensures that every problem is analyzed systematically and based on data before solutions are implemented. DMAIC consists of the following stages:

1. Define – Identifying the problems that occur and determining Critical to Quality (CTQ) characteristics. At this stage, quality standards that must be achieved are also determined.

2. Measure – Collecting data to measure the actual process performance such as defect rate, DPMO, and sigma level.

3. Analyze – Identifying the root causes of variations or defects. Statistical analysis is used to determine the dominant factors affecting product nonconformities.

4. Improve – Implementing solutions based on the results of the previous analysis.

5. Control – Maintaining the sustainability of improvement results through continuous monitoring and control using statistical tools.

Several recent studies in Indonesia have demonstrated the effectiveness of Six Sigma and the DMAIC methodology in improving product quality across various manufacturing sectors.

A study by Sumasto et al. (2023), entitled "Enhancing Automotive Part Quality in SMEs through DMAIC Implementation: A Case Study in Indonesian Automotive Manufacturing," was conducted in an automotive component manufacturing SME in Indonesia. The results showed that the implementation of DMAIC reduced DPMO from 22,230 to 2,339 and increased the sigma level from 3.51 to 4.33, indicating a significant improvement in process capability. Another study by Sinaga and Suseno (2023), titled "Upaya Meningkatkan Kualitas Produk Manhole Menggunakan Metode Six Sigma di PT XYZ," was conducted in a metal casting industry in Indonesia. The study reported a defect rate of 3.51% with a DPMO value of 17,527.68 and a sigma level of 3.61. Improvement efforts focused on human, machine, method, and material factors using 5W+1H analysis. Kartika et al. (2024), in their study "Lowering Customer Claim & NG Ratio on Jack Bracket Part Using

Lean Six Sigma-DMAIC Method at PT XYZ," conducted research in a manufacturing company producing automotive components. The results showed that defect levels decreased from 32,325 PPM to 7,500 PPM, and the sigma level improved from 3.3 to 4.0 after implementing Six Sigma.

Wildan and Santosa (2024) conducted a study titled "Analisis Pengendalian Kualitas pada Proses TIG Welding Menggunakan Metode DMAIC di PT Dirgantara Indonesia." This research focused on the welding process in the aerospace manufacturing industry. The findings indicated that machine-related factors were the dominant causes of defects, emphasizing the importance of root cause analysis using fishbone diagrams. Saidatuningtyas and Rizal (2023), in their study "Analisis Pengendalian Kualitas Produk Konstruksi Baja untuk Jembatan Menggunakan Metode Six Sigma DMAIC," examined a steel fabrication industry in Indonesia. The results identified that production errors were the most significant contributors to defects, with major causes originating from material, man, machine, and method factors. Additionally, Bayu et al. (2023) conducted a study titled "Quality Control of Electrical Panel Powder Coating Box Production Using the DMAIC Six Sigma Method at PT DMI Tangerang." The study found an average DPMO value of 4,107.49 and a sigma level of 4.175, with improvements achieved through SOP development and process standardization

Most of the reviewed studies are conducted in local industrial contexts, which are highly relevant to the characteristics of manufacturing systems in developing countries. These studies consistently demonstrate that the DMAIC methodology is effective in reducing defects and improving process performance. However, several research gaps remain. Most previous studies focus primarily on defect reduction at the product level rather than analyzing root causes in a structured and quantitative manner. In addition, the application of advanced statistical validation techniques such as regression and ANOVA is still limited. Furthermore, only a few studies evaluate the robustness of risk prioritization using sensitivity analysis, particularly in the context of cause-based FMEA derived from fishbone diagrams.

Therefore, this study aims to address these gaps by integrating DMAIC methodology with root cause-based RPN analysis and statistical validation methods, including descriptive statistics, correlation, regression, and sensitivity analysis. This approach is expected to provide a more comprehensive and reliable framework for quality improvement and decision-making in manufacturing processes. However, there is still a need to integrate these findings with broader global perspectives to enhance the generalizability of the results.

RESEARCH METHODOLOGY

This study is quantitative research using a case study approach conducted at PT XYZ. The approach used is Six Sigma with the DMAIC (Define, Measure, Analyze, Improve, Control) cycle as the problem-solving framework. Seven Tools of Quality are used as instruments in the Measure, Analyze, and Control stages to identify dominant defects, analyze root causes, and monitor production stability.

The data used in this study consist of primary and secondary data. Primary data were obtained through direct observation of the welding process, interviews with operators, and recording the number and types of defects using check sheets. Secondary data were obtained from production reports, company quality standards, and operational procedure documents for the welding process.

RESULT AND DISCUSSION

Define

At this initial stage, identification of problems occurring in the welding process at PT XYZ was carried out, as well as determining the critical quality characteristics or CTQ (Critical to Quality).

Date	Planning	Holes	Porosity	Insufficient	Misaligned	Spatter	TOTAL
05/01/2026	500	12	10	8	13	8	51
06/01/2026	500	13	10	11	13	12	59
07/01/2026	500	21	8	10	16	6	61
08/01/2026	500	17	12	13	21	15	78

09/01/2026	500	13	9	9	17	7	55
12/01/2026	500	15	9	9	13	6	52
13/01/2026	470	9	8	8	14	12	51
14/01/2026	500	16	12	8	17	13	66
15/01/2026	500	10	9	10	8	8	45
19/01/2026	500	16	12	15	17	12	72
20/01/2026	430	19	10	12	10	9	60
21/01/2026	500	18	12	11	23	12	76
22/01/2026	500	21	12	11	19	13	76
23/01/2026	500	24	15	12	13	10	74
26/01/2026	500	13	7	10	12	7	49
27/01/2026	500	14	12	8	23	13	70
28/01/2026	480	15	10	7	13	14	59
29/01/2026	500	17	9	13	15	11	65
30/01/2026	500	13	8	7	7	8	43
02/02/2026	500	22	12	12	21	15	82
03/02/2026	500	15	10	21	16	12	74
04/02/2026	420	17	8	12	13	12	62
05/02/2026	500	24	10	16	11	12	73
Total	**11300**	**374**	**234**	**253**	**345**	**247**	**1453**

Table 1. Defect Welding Data

Based on the table above, the total number of defects was 1,453 pcs, consisting of 374 holes welding defects, 345 misaligned welding defects, 253 insufficient welding defects, 247 porosity welding defects, and 234 spatter defects. The following is a Histogram showing the percentage of each welding defect.

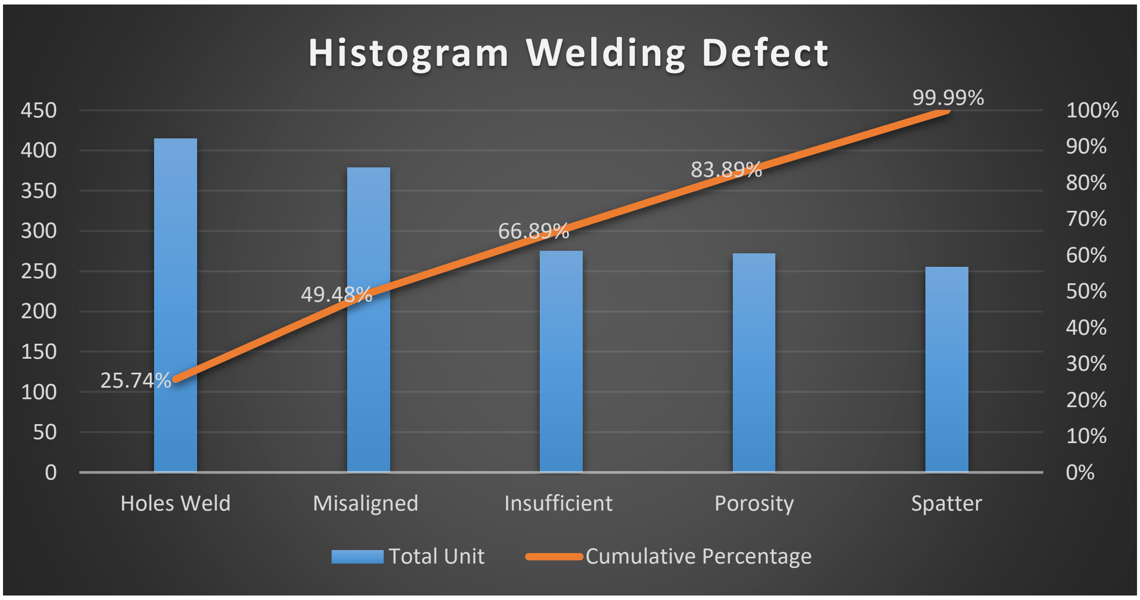

Diagram 1. Histogram Welding Defect

From the diagram, it can be seen that the highest percentage of defects is welding holes at 25.74%, the second is misaligned defects at 23.74%, the third is insufficient at 17.41%, porosity at 17.00% and spatter at 16.10%. The following shows the histogram of welding defects along with the cumulative percentage.

Defect Type	Total Unit	Percent	Total Percent
Holes Weld	374	**25,74%**	**25,74%**
Misaligned	345	**23,74%**	**49,48%**
Insufficient	253	**17,41%**	**66,89%**

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Porosity	247	**17,00%**	**83,89%**
Spatter	234	**16,10%**	**99,99%**
Total	**1453**	**99,99%**	

Table 2. Percentage of Welding Defects.

In this study, the analysis focused on the three defects with the highest percentage as the main priority for repair. Based on the table above, the three highest defects for repair are holes welding at 25.74%, misaligned at 23.74%, and insufficient at 17.41%.

Measure

At this stage, DPMO and sigma level calculations were conducted . Based on the data on the table production in January 05, 2026, total production 500, with defects 51 and there are 5 types of defect. The calculation steps are presented below :

1. Total Opportunity Calculation (TOP)

TOP = Unit (U) x Opportunity
TOP = 500 x 5
TOP = 2500

2. Defects Per Opportunity (DPO)

DPO = $\frac{Total\ Defect}{TOP}$
DPO = $\frac{51}{2500}$ = 0,0204

3. Defect Per Million Opportunity

DPMO = DPO x 1.000.000
DPMO = 0,0204 x 1.000.000
DPMO = 20.400

4. Level Sigma

Sigma = NORMSINV(1-(DPMO/1.000.000) + 1.5
Sigma = NORMSINV(1-(20.400/1.000.000) + 1.5
Sigma = 3,54

Based on the calculations for the production activity on January 02, 2026, the Total Opportunity (TOP) value was 2500, meaning there were 2500 opportunities for defects to occur in one production day. The Defect Per Opportunity (DPO) value was 0.0204, indicating that each product had a defect probability of 0.0204. The DPMO value was 20.400, meaning that out of 1,000,000 opportunities, approximately 20.400 defects were found. The sigma level was 3.54, indicating that the production process was at a good level but still required improvement to become more optimal.

The following is a table of calculations for Total Opportunity (TOP), Defect Per Opportunity (DPO), and Defect Per Million Opportunity (DPMO) during the period January 05, 2026 – February 05, 2026

Date	**Planning**	**Defect**	**TOP**	**DPO**	**DPMO**	**Sigma**
05/01/2026	500	51	2500	0,0204	20400	3,5455568
06/01/2026	500	59	2500	0,0236	23600	3,4845012
07/01/2026	500	61	2500	0,0244	24400	3,4703349
08/01/2026	500	78	2500	0,0312	31200	3,3634428
09/01/2026	500	55	2500	0,022	22000	3,5140908
12/01/2026	500	52	2500	0,0208	20800	3,5374996
13/01/2026	470	51	2350	0,0217021	21702,128	3,5197989

14/01/2026	500	66	2500	0,0264	26400	3,4365531
15/01/2026	500	45	2500	0,018	18000	3,5969274
19/01/2026	500	72	2500	0,0288	28800	3,3987299
20/01/2026	430	60	2150	0,027907	27906,977	3,4124855
21/01/2026	500	76	2500	0,0304	30400	3,3749471
22/01/2026	500	76	2500	0,0304	30400	3,3749471
23/01/2026	500	74	2500	0,0296	29600	3,3867051
26/01/2026	500	49	2500	0,0196	19600	3,5620813
27/01/2026	500	70	2500	0,028	28000	3,4110356
28/01/2026	480	59	2400	0,0245833	24583,333	3,4671435
29/01/2026	500	65	2500	0,026	26000	3,4431338
30/01/2026	500	43	2500	0,0172	17200	3,6153515
02/02/2026	500	82	2500	0,0328	32800	3,3411471
03/02/2026	500	74	2500	0,0296	29600	3,3867051
04/02/2026	420	62	2100	0,0295238	29523,81	3,3878386
05/02/2026	500	73	2500	0,0292	29200	3,3926833
Average			**2456,5217**	**0,0257442**	**25744,185**	**3,4473869**

Table 3. Daily Calculation DPMO and Sigma Level

The average DPMO value during the period January 05, 2026 – February 05, 2026 was 25744,185 with an average sigma level of 3.44.

Analyze

The analyze phase aims to identify and validate the root causes of welding defects through a structured and data -driven approach. This study integrates qualitative and quantitative methods, including fishbone diagram analysis, statistical validation using ANOVA and RPN sensitivity analysis.

From the three defects with the highest frequency, an analysis of the causes was conducted using fishbone diagrams. The analysis focused on identifying the dominant root causes based on four main factors: Man, Machine, Method, and Material

1. Holes Welding Defect, here is a fishbone diagram of hole welding defects

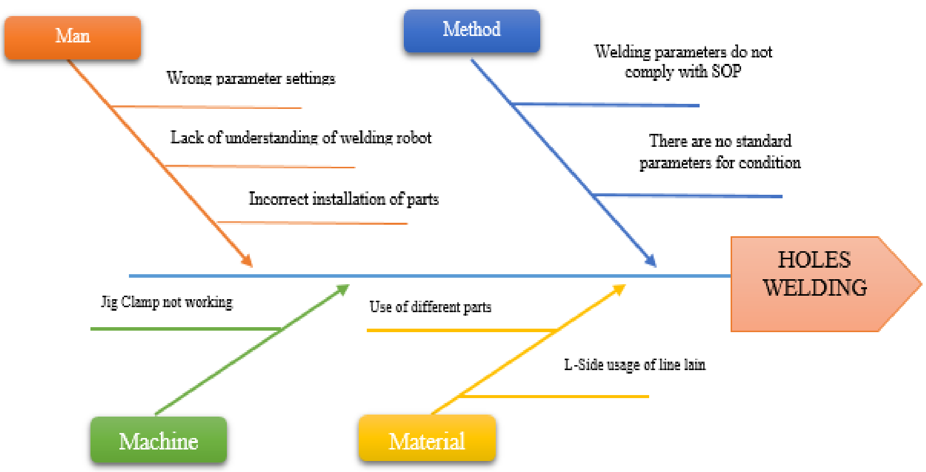

Diagram 2. Fishbone Diagram Welding Holes Defect

Based on the fishbone diagram, welding holes defects are caused by four main factors.

Man

This factor is caused by errors in welding parameter settings, where the most common mistake is excessive amperage. Excessive amperage can cause the welding results to become perforated. Another cause is that operators do not fully understand the welding robot program. Different production types require specific program adjustments, and if the running production type does not match the selected program, the welding result may become perforated. In addition, improper part installation on the jig can also cause welding holes because the welding position becomes inaccurate, especially in thin areas of the material.

Method

The method factor is caused by welding parameters that do not comply with Standard Operating Procedures (SOP), such as excessive amperage and voltage settings. These unsuitable parameters can cause holes in the welding results. Another issue is the absence of standard parameter settings for different production variations. Different product types require different welding parameters; therefore, parameter standardization is necessary for each production type.

Machine

The machine factor is caused by malfunctioning jig clamps. The jig clamp functions to lock the body frame position during the welding process. If the jig clamp does not function properly, the workpiece position may shift, causing the welding point to move and increasing the possibility of welding holes.

Material

The material factor is caused by the use of parts from different suppliers, such as Stay Floor R & L components. Different suppliers may produce parts with slightly different dimensions, resulting in inconsistent welding quality. In addition, the use of L-side components from other production lines can also affect welding quality because these components may have different dimensions.

Misaligned Welding Defect, below is a fishbone diagram of misaligned welding defect.

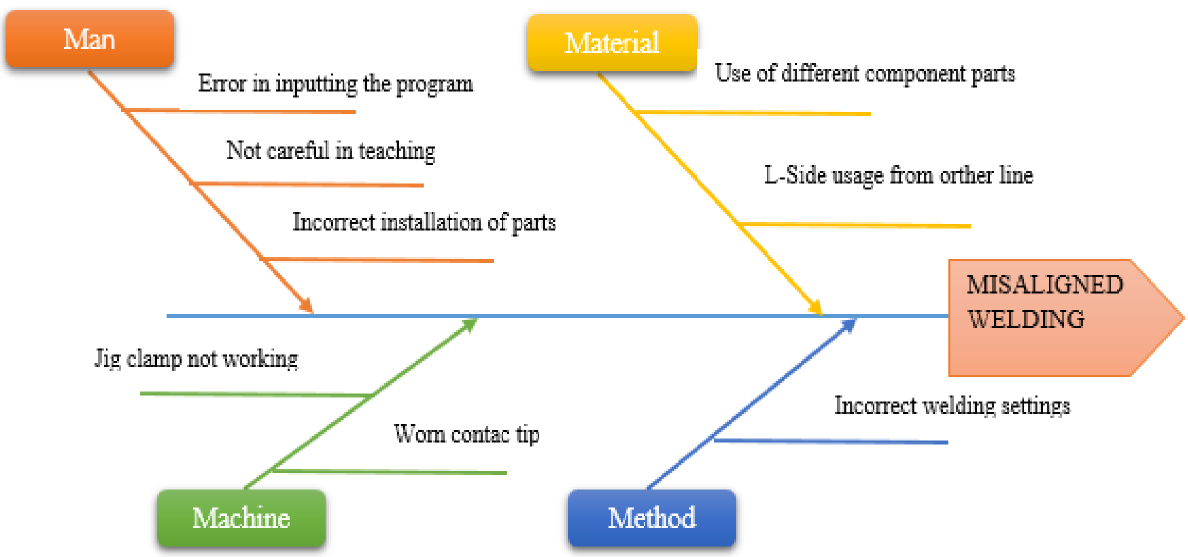

Diagram 3. Fishbone Diagram Misaligned Welding Defect

Based on the fishbone diagram, misaligned welding defects are caused by four main factors :

Man

The first factor is human error, which includes mistakes in entering welding programs. If the program entered does not match the running production type, the welding result may become misaligned. Another cause is the operator's lack of accuracy during the teaching process, which may result in incorrect welding positions. Improper part installation on the jig can also contribute to welding misalignment

Material

The material factor is caused by the use of different parts and L-side components from other production lines. Differences in dimensions between components can affect the welding position and result in misaligned welding defects.

Machine

The machine factor is caused by malfunctioning jig clamps, similar to the welding holes defect. When the jig clamp cannot properly lock the body frame, the workpiece position may shift and alter the welding point position. Another machine-related issue is worn contact tips. A worn contact tip causes the welding point focus to become unstable, which can lead to inaccurate welding positions

Method

The method factor is caused by improper welding settings. Incorrect welding settings can affect the teaching process and result in welding positions that do not match the required points.

Insufficient Welding Defect, below is a fishbone diagram of insufficient welding defect

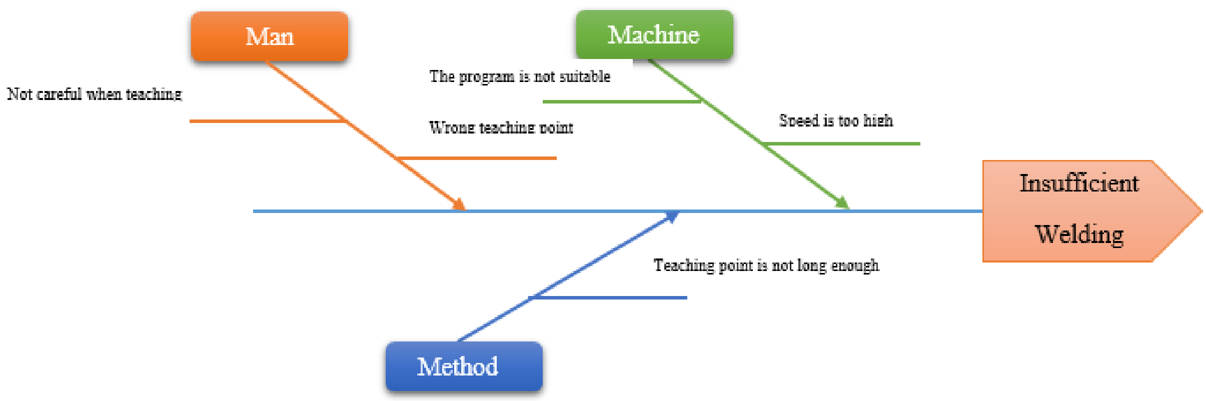

Diagram 4. Fishbone Diagram Insufficient Welding Defect

Based on the fishbone diagram, insufficient welding defects are caused by three main factors :

Man

The first factor is the operator's lack of accuracy during the teaching process and in determining welding points. Inaccurate teaching points can cause incomplete welding lengths, resulting in insufficient welding defects.

Machine

The machine factor is caused by welding programs that do not match the running production type. Different programs can produce different welding lengths, causing incomplete welds. Another cause is excessively high robot speed, which may reduce welding quality and produce insufficient weld lengths.

Method

The method factor is caused by teaching points that do not reach the edge of the welding area. As a result, the welding process does not fully cover the required welding area, leading to insufficient welding defects.

Anova Test

A one way ANOVA test was conducted to determine whether there are statistically significant differences in defect level under different process conditions. The analysis was based on daily welding defect data collected over 23 observations (Table 1.Defect Welding Data). To enable comparison, the defect data were classified into three groups (KELOMPOK 1, KELOMPOK 2, KELOMPOK 3) using quantile – based approach. Kelompok 1 represents the lowest defect values (49 – 55), Kelompok 2 represents moderate defect levels (59 – 66), and Kelompok 3 represents the highest defect values (70 – 82).

The hypotheses for the ANOVA test are defined as follows :

H0 : There is no significant difference in defect levels between groups

H1 : There is a significant difference in defect levels between groups.

The ANOVA test compares the variance between groups and within groups to evaluate whether the observed differences are statistically significant. The following are the results of the ANOVA test

ANOVA					
DFC					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2703.672	2	1351.836	107.877	.000
Within Groups	275.688	22	12.531		
Total	2979.360	24			

Table 4. ANOVA Result

The results show that the between groups variance (Sum of Square = 2703.672) is significantly higher than the within groups variance (Sum of Square = 275.688). The calculated F-Value is 107.877 with significance value of $p < 0.001$. Since the p-value is lower than significance level of 0,05 the null hypothesis is rejected. This indicates that there are statistically significant differences in defect levels between the groups. This result confirms that variations in process conditions significantly influence welding defects and are not caused by random variation. Therefore, further analysis of root cause is justified . Following ANOVA results, a post hoc test using tukey HSD was conducted to identify pairwise differences between groups. The following is result of the post hoc test.

Multiple Comparisons						
Dependent Variable: DFC						
Bonferroni						
(I) KELOMPOK	(J) KELOMPOK	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
KELOMPOK 1	KELOMPOK 2	-12.28571*	1.89219	.000	-17.1888	-7.3827
	KELOMPOK 3	-24.93506*	1.71155	.000	-29.3700	-20.5001
KELOMPOK 2	KELOMPOK 1	12.28571*	1.89219	.000	7.3827	17.1888
	KELOMPOK 3	-12.64935*	1.71155	.000	-17.0843	-8.2144
KELOMPOK 3	KELOMPOK 1	24.93506*	1.71155	.000	20.5001	29.3700
	KELOMPOK 2	12.64935*	1.71155	.000	8.2144	17.0843
*. The mean difference is significant at the 0.05 level.						

Table 5. Post Hoc Test Result

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The results show that all group comparisons are statistically significant (p = 0.000), indicating that each group has a distinct defect level .This confirms that the classification into three groups effectively represent different process performance condition .

RISK PRIORITY NUMBER (RPN) METHOD

At this stage, a sensitivity analysis is conducted on the Risk Priority Number (RPN). Previously, the author had compiled an RPN for each defect to analyze the causes that significantly influence the occurrence of defects.. The RPN method was carried out by assigning scores on a scale of 1–5 based on Severity (S), Occurrence (O), and Detection (D). Severity (S) indicates how serious the impact of the defect cause is on the product. Occurrence (O) indicates how often the defect cause occurs. Detection (D) indicates how easily the defect cause can be identified. The RPN value was calculated using the following formula, RPN = Severity × Occurrence × Detection. Below is the RPN calculation for each defects

1. Holes Welding Defect

RPN TABLE HOLES WELDING DEFECT					
Factor	**Cause of Defect**	**S**	**O**	**D**	**RPN**
Man	Incorrect parameter setting	4	5	3	60
	Lack of understanding of the welding robot program	2	4	2	16
	Improper part installation	2	3	4	24
Method	Welding parameters not in accordance with SOP	4	4	3	48
	No parameter standard for varying conditions	3	3	3	27
Machine	Jig clamp not functioning properly	2	5	5	50
Material	Use of different parts	2	4	5	40
	Use of L-Side from another line	2	4	5	40

Table 6. RPN Holes Welding Defect

Based on the table above, the three highest RPN values were incorrect parameter settings (RPN 60), malfunctioning jig clamps (RPN 50), and welding parameters not according to SOP (RPN 48). These causes became the top priorities for improvement.

RPN Table Misaligned Welding Defect

RPN TABLE MISALIGNED WELDING DEFECT					
Factor	**Cause of Defect**	**S**	**O**	**D**	**RPN**
Man	Error in inputting the program	4	5	3	60
	Lack of accuracy during teaching process	2	5	3	30
	Improper part installation	2	3	4	24
Method	Incorrect welding settings	4	4	4	64
Machine	Worn contact tip	3	5	5	75
	Jig clamp not functioning properly	2	5	5	50
Material	Use of different parts	2	4	5	40
	Use of L-Side from another line	2	4	5	40

Table 7. RPN Misaligned Welding Defect

Based on the table above, the highest RPN value was worn contact tips with an RPN of 75, followed by improper welding settings with an RPN of 64, and program input errors with an RPN of 60. These three causes became the main improvement priorities.

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RPN Table Insufficient Welding Defect

RPN TABLE INSUFFICIENT WELDING DEFECT					
Factor	**Cause of Defect**	**S**	**O**	**D**	**RPN**
Man	Lack of accuracy during teaching process	2	4	5	40
	Errors during teaching point process	3	4	5	60
Machine	Program not appropriate	2	3	2	12
	Robot speed too high	3	5	2	30
Method	Teaching point does not reach the edge	2	4	5	40

Table 8. RPN Insufficient Welding Defect

Based on the table above, the highest RPN value was incorrect teaching points with an RPN of 60. The next priorities were lack of accuracy during teaching and teaching points not reaching the edge, both with an RPN of 40.

Sensitivity Analysis

Sensitivity analysis was conducted to evaluate the robustness of the Risk Priority Number (RPN) in representing the level of risk for each identified failure mode. The main objective of this analysis is to assess how variations in the input variables—Severity (S), Occurrence (O), and Detection (D)—influence the resulting RPN values and to ensure the stability of the prioritization. To support this analysis, statistical methods including descriptive statistics, correlation analysis, and regression analysis were applied. Descriptive statistics were used to provide an overview of the distribution and variability of S, O, D, and RPN values. This helps identify the range, central tendency, and consistency of the data.

Correlation analysis was performed to examine the strength and direction of relationships between S, O, D, and RPN. This analysis helps to understand how changes in each variable are associated with changes in risk levels. Furthermore, regression analysis was conducted to evaluate the relative contribution of each variable to the RPN. This allows identification of the most influential factor affecting risk prioritization. Overall, this integrated approach provides a comprehensive understanding of the behavior of the RPN model and supports the reliability of decision-making in determining improvement priorities.

Sensitivity analysis was conducted on the critical causes identified from each defect category. For each defect, the three causes with the highest RPN values were selected, resulting in a total of nine critical causes. This approach ensures that the analysis represents all major defect categories and provides a comprehensive evaluation of risk sensitivity. Below is a table with the three highest RPN for each defect

Defect Type	Factor	Cause of Defect	S	O	D	RPN
Holes Welding	Man	Incorrect parameter setting	4	5	3	60
	Machine	Jig clamp not functioning properly	2	5	5	50
	Method	Welding parameters not in accordance with SOP	4	4	3	48
Misaligned Welding	Machine	Worn contact tip	3	5	5	75
	Method	Incorrect welding settings	4	4	4	64
	Man	Error in inputting the program	4	5	3	60
Insufficient Welding	Man	Errors during teaching point process	3	4	5	60
		Lack of accuracy during teaching process	2	4	5	40
	Method	Teaching point does not reach the edge	2	4	5	40

Table 9. Highest RPN From Each Defect

The data from the table is used as a reference in conducting a sensitivity analysis. The following are the steps in conducting sensitivity analysis.

Descriptive Statistics

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
S	9	2.00	4.00	3.1111	.92796
O	9	4.00	5.00	4.4444	.52705
D	9	3.00	5.00	4.2222	.97183
rpn	9	40.00	75.00	55.2222	11.61656
Valid N (listwise)	9				

Table 10. Descriptive Statistics Results

Based on the results of descriptive analysis of 9 data points, it was found that the Severity (S) variable has an average value of 3.11 with a standard deviation of 0.93, indicating that the level of severity is in the moderate category with relatively small variation. The Occurrence (O) variable has an average of 4.44 with a standard deviation of 0.53, indicating that the frequency of occurrence is quite high and tends to be homogeneous. Meanwhile, the Detection (D) variable has an average of 4.22 with a standard deviation of 0.97, indicating that the detection capability is in the high category with moderate variation. Furthermore, the Risk Priority Number (RPN) has an average value of 55.22 with a standard deviation of 11.62, indicating that the level of risk is in the medium to high category with a fairly large data dispersion.

Correlation Analysis

Correlations					
		S	O	D	rpn
S	Pearson Correlation	1	.142	-.862**	.542
	Sig. (2-tailed)		.716	.003	.131
	N	9	9	9	9
O	Pearson Correlation	.142	1	-.217	.492
	Sig. (2-tailed)	.716		.575	.178
	N	9	9	9	9
D	Pearson Correlation	-.862**	-.217	1	-.149
	Sig. (2-tailed)	.003	.575		.702
	N	9	9	9	9
rpn	Pearson Correlation	.542	.492	-.149	1
	Sig. (2-tailed)	.131	.178	.702	
	N	9	9	9	9
**. Correlation is significant at the 0.01 level (2-tailed).					

Table 11. Correlation Analysis Results

Based on the correlation analysis using Pearson correlations on 9 observations, it was found that the relationship between Severity (S) and Detection (D) is strong, negative, and statistically significant ($r = -0.862$, $p = 0.003$). This indicates that as severity increases, the detection value tends to decrease. Meanwhile, the relationship between severity (S) and Occurrence (O), ($r = 0.142$, $p = 0.716$), Severity (S) and Risk Priority Number (RPN), ($r = 0.542$, $p = 0.131$), Occurrence (O) and Detection (D), ($r = -0.217$, $p = 0.575$), Occurrence (O) and RPN, ($r = 0.492$, $p= 0.178$), and detection and RPN ($r = -0.149$, $p = 0.702$) are not statistically significant. These results indicate only severity has a significant relationship with detection, while other variables do not show a significant correlation with is constituent variables (S,O and D), even though theoretically RPN is calculated as the product of these three variables. The lack of statistical significance may be attributed to the small sample size ($n = 9$) and the limited variability in S, O, and D values, which may reduce the statistical power of the analysis. Therefore, the interpretation of RPN in this study is primarily based on its ranking and practical implications rather than statistical correlation.

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Regression Analysis

Based on the regression output, the model demonstrates a very strong relationship between independent variables (Severity, Occurrence, and Detection) and the dependent variable (Risk Priority Number)

Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.996[a]	.992	.987	1.32647
a. Predictors: (Constant), D, O, S				

Table 12. Model Summary

The model summary shows that the correlation coefficient (R) is 0.996, indicating very strong linear relationship between the variables. The coefficient of determination (R Square) is 0.992 which means that 99.2% of the variation in RPN can be explained by severity (S), Occurrence (O) and Detection (D). the remaining 0.8% is influenced by other factors outside the model. The adjusted R Square value of 0.987 confirms that the model remains highly reliable even after adjustment. Additionally, the standard error of the estimate is 1.32647, indicating a relatively low prediction error.

ANOVA Test

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1070.758	3	356.919	202.850	.000[b]
	Residual	8.798	5	1.760		
	Total	1079.556	8			
a. Dependent Variable: rpn						
b. Predictors: (Constant), D, O, S						

Table 13. ANOVA Results

The ANOVA test results show that the F-value is 202. 850 with a significance level of 0.000, which is less than 0.05. This indicates that regression model is statistically significant, meaning that the independent variables (S,O and D) simultaneously have a significant effect on RPN.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-140.167	8.597		-16.305	.000
	S	21.476	1.003	1.716	21.418	.000
	O	12.429	.915	.564	13.578	.000
	D	17.369	.971	1.453	17.890	.000
a. Dependent Variable: rpn						

Table 14. Regression Coefficients

The regression equation derived from the coefficients table is as follows :

RPN = -140.167 + 21.476S + 12.429O + 17.369D

From the partial (t-test) results, all independent variables have a significance value of 0.000, which is below 0,05. This is indicates that each individually has a significant positive effect on RPN.

- Severity (S) has a coefficient of 21.476, indicating that an increase in severity leads to a significant increase in RPN

- Occurrence (O) has a coefficient of 12.429, showing a positive and significant influence on RPN
- Detection (D) has a coefficient of 17.369, also indicating a positive and significant effect.

Based on the standardized coefficients (Beta), Severity (β = 1.716) has the strongest influence on RPN, followed by detection (β = 1.453) and Occurrence (β = 0.546)

The regression model is highly significant and explains the variation in RPN very well. All independent variables, Severity, Occurrence, and Detection, have a positive significant effect on RPN, with severity being the most dominant factor influencing the Risk Priority Number.

Improvement

At this stage, improvement plans were developed based on the root cause analysis conducted during the Analyze stage. Improvements focused on dominant causes contributing to the three main defect types. In this study, corrective actions were prepared using the 5W + 1H approach. This approach was used to formulate systematic and effective improvement activities that could be implemented directly in the production area.

1. Holes Welding Defect

5W + 1H Table Holes Welding Defect	
What	Incorrect parameter settings, welding parameters not in accordance with SOP, and the jig clamp not functioning properly
Why	Operators do not fully understand the standard welding parameters, differences between shift operators cause parameter variations, and the jig is not in good condition.
Where	Welding area at each working station.
When	Before production starts.
Who	Production operators and line leaders
How	Conduct training, especially for technicians and operators, on parameter setting procedures. Create welding parameter standardization. Perform autonomous maintenance before starting production and conduct periodic maintenance on the jig

Table 15. 5W + 1H Holes Welding Defect

The table explains the factors causing Holes welding defects, where holes or cavities appear in the weld results due to unstable welding conditions. The main causes include incorrect welding parameter settings, welding parameters that do not follow the Standard Operating Procedure (SOP), and jig clamps that do not function properly. These problems occur because operators do not fully understand the welding parameter standards and because different shift operators use different parameter settings. In addition, poorly maintained jigs can reduce welding accuracy and stability.

This defect generally occurs in the welding area at each working station before production activities begin. Therefore, both production operators and line leaders have an important role in preventing the defect. Corrective actions include conducting training for technicians and operators regarding proper parameter settings, creating standardized welding parameters, performing autonomous maintenance before production starts, and carrying out regular jig maintenance to ensure stable welding quality.

Misaligned Welding Defect

5W + 1H Table Misaligned Welding Defect	
What	Errors in program input, improper welding settings, and worn contact tip
Why	Operators input the wrong welding program code for the running model type, there is no standard for determining welding points, and no periodic inspection is carried out on the contact tip being used.

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Where	Welding area at each working station.
When	Before production starts
Who	Production operators and line leaders
How	Operators perform repeated checks before running the program to ensure the entered program is correct, create SOP related to determining welding points, and conduct periodic inspections of the contact tip.

Table 16. 5W + 1H Misaligned Welding Defect

The table describes the causes of misaligned welding defects, where the welding position does not match the required welding point. The defect is mainly caused by errors in program input, improper welding settings, and worn contact tips. These issues occur because operators may input the wrong welding program code for the running model type, there is no clear standard for determining welding points, and periodic inspections of the contact tip are not consistently inspected.

This problem usually occurs in the welding area at each working station before production starts. The responsibility for controlling this defect lies with production operators and Line Leaders. Preventive actions include performing repeated program checks before operation, creating SOPs for determining welding points, and conducting routine inspections of the contact tip to maintain welding precision and overall product quality.

Insufficient Welding Defect

5W + 1H Insufficient Welding Defect	
What	Errors in performing teaching points and excessively high robot speed
Why	Operators lack the skills to perform robot teaching properly, and welding speed parameters are not adjusted according to the model type.
Where	Welding area at each working station.
When	During production activities.
Who	Production operators and line leaders
How	Conduct robot teaching training, especially for technicians and robot operators, and adjust the welding robot speed limits for various model types

Table 17. 5W + 1H Insufficient Welding Defect

The table explains the causes of Insufficient welding defects, which occur when some welding points are not properly welded during the production process. The main causes are errors in performing teaching points and excessively high robot speed. These problems arise because operators may lack sufficient skills in robot teaching procedures, and the welding speed parameters are sometimes not adjusted according to the specific model type being produced.

This defect generally occurs during production activities in the welding area at each working station. Production operators and Line Leaders are responsible for monitoring and controlling the welding process to prevent this issue. Improvement actions include providing robot teaching training for technicians and robot operators, as well as adjusting the welding robot speed limits according to different model types. These actions can improve welding accuracy, reduce defects, and increase production quality consistency.

RESULTS

The following shows the results of the improvements made in the form of data on the reduction in the number of defects and sigma before and after the improvements were made.

Period	Production	Total Defect	Sigma	Before/After
5 January - 5 February	11,300	1,453	3.44	Before Improvement
23 February - 2 April	11,050	1,216	3.53	After Improvement
6 April - 30 April	11,500	978	3.61	

Table 18. Improvement Results

Based on the table, the sigma value for the period January 5 - February 5 was at 3.44 with a total of 1,453 defects. After the improvement was carried out, there was an increase in the sigma value and a decrease in the number of defects. The period February 23 - April 2 showed the sigma value at 3.53, this figure increased by 2.62% from the previous period and the number of defects decreased to 1,216, this figure decreased by 16.31% from the previous period. In the period April 6 - April 30, the sigma value was at 3.61, this figure increased by about 2.27% from the previous period, and the number of defects decreased to 978, this figure decreased by about 19.57% from the previous period. The decrease in the number of defects and the increase in the sigma value indicate a significant increase in process quality. This indicates that an increase in the sigma level, although relatively small, has a large impact on reducing production defects.

Control

The control stage in the DMAIC method is carried out to ensure that all improvement actions that have been implemented can run consistently and continue to provide optimal results in the production process. At this stage, the company focuses on maintaining process stability, reducing the possibility of recurring defects, and ensuring that all operators follow the established standards. Several control steps that can be implemented by the factory include:

Creating and Implementing Standard Operating Procedures (SOPs)

The company must establish clear SOPs for welding parameter settings, robot teaching procedures, machine inspections, and maintenance activities. These standards help operators perform work consistently and reduce process variations.

Conducting Routine Monitoring and Inspections

Production operators and Line Leaders should perform regular inspections before and during production activities. Monitoring includes checking welding parameters, machine conditions, jig conditions, robot speed, and welding results to ensure that all processes remain within the standard limits.

Using Checklists and Control Sheets

Daily checklists and control sheets should be used to record machine settings, maintenance activities, inspection results, and production conditions. This documentation helps the company identify abnormalities quickly and ensures that improvement actions are consistently applied.

Performing Preventive and Autonomous Maintenance

Regular preventive maintenance for welding machines, robots, jigs, and supporting equipment is necessary to maintain equipment performance and prevent breakdowns that may cause defects. Operators can also perform autonomous maintenance before production starts to ensure machines are in good condition.

Providing Continuous Training and Skill Evaluation

The company should conduct periodic training for operators and technicians regarding welding standards, robot operation, parameter settings, and quality control procedures. Regular skill evaluations help ensure that employees maintain competency and follow the latest standards.

Conducting Periodic Audits and Performance Reviews

Supervisors and quality control teams should conduct regular audits to evaluate compliance with SOPs and assess the effectiveness of implemented improvements. Production defect data and process performance should also be reviewed continuously to identify opportunities for further improvement.

By implementing these control activities consistently, the factory can maintain the improvements that have been achieved, reduce production defects, improve product quality, and ensure that the production process continues to operate effectively and efficiently over the long term.

CONCLUSION

Based on the results of the quality control analysis, the following conclusions can be drawn:

1. The most frequent defects in the body frame welding process were welding holes (374 pcs), misaligned welding (345 pcs), and insufficient welding (253 pcs).
2. The DPMO measurement results showed an average value of 25,744.185 with an average sigma level of 3.44. This value indicates that quality control is categorized as good but still has room for improvement.
3. Based on the fishbone diagram analysis, the main root causes of welding defects were human factors, machine factors, method factors, and material factors.
4. Improvement priorities were determined to identify which causes required immediate corrective action by considering the frequency and impact of each defect cause. Improvements using the 5W + 1H method showed that machine and human factors were dominant causes of welding defects. Therefore, improvements focused on welding parameter standardization, periodic machine component replacement, and improving operator accuracy through training and supervision.
5. The implementation of the Six Sigma method with the DMAIC approach proved to provide a structured and systematic way to identify, analyze, and continuously improve quality problems

RECOMMENDATIONS

1. PT XYZ should standardize welding parameters for each product type to minimize variation in the welding process and reduce the occurrence of welding defects.
2. The company should provide regular training and evaluation for welding operators, especially regarding robot welding programs, teaching points, and machine parameter settings.
3. Preventive maintenance activities should be carried out routinely on welding machines and supporting equipment such as jig clamps and contact tips to ensure stable machine performance during production.
4. PT XYZ should strengthen inspection and monitoring activities during the production process to detect welding defects earlier and prevent defective products from continuing to the next process.
5. Future researchers are encouraged to develop this study by applying other quality improvement methods or integrating additional statistical tools to obtain more comprehensive results.

REFERENCES

1. Amalliyah, N., & Nugraha, I. (2025). Analisis Pengendalian Kualitas Hasil Pengelasan Bengkel Welding HO & AO di PT. A Menggunakan Metode Six Sigma dan New Seven Tools. Industrika: Jurnal Ilmiah Teknik Industri, 9(2). https://doi.org/10.37090/indstrk.v9i2.2058 (Jurnal UTB)
2. Fatoni, F. A., & Yuamita, F. (2026). Analisis Pengendalian Kualitas Produk Menggunakan Metode Six Sigma pada Perusahaan Manufaktur Logam. Jurnal Ilmiah Research Student, 3(1). https://doi.org/10.61722/jirs.v3i1.8697 (Kampus Akademik)
3. Fadila, Y. A., Widi, R. A. A., & Oganda, D. D. (2025). Optimasi Kualitas Produk Stamping Dengan Metode Six Sigma DMAIC. Jurnal Teknologi dan Manajemen Industri Terapan, 4(4). https://doi.org/10.55826/jtmit.v4i4.1111 (Jurnal TMIT)

4. Fernandha, P. W., Ahmad, & Doaly, C. O. (2024). Pengendalian Kualitas Produk Pipa pada Pump in Roll di PT. XYZ dengan Menggunakan Metode Six Sigma. Jurnal Mitra Teknik Industri, 3(1). https://doi.org/10.24912/jmti.v3i1.29731 (Journal Untar)
5. Firmansyah, R., Khofiyah, N. A., & Suhendra. (2025). Pengendalian Kualitas Dengan Menggunakan Metode Six Sigma DMAIC untuk Menurunkan Cacat Produk Block Mesin 4TNV 107 di PT. XYZ. Matrik: Jurnal Manajemen dan Teknik Industri Produksi, 26(1). https://doi.org/10.30587/matrik.v26i1.10108 (Journal of UMG)
6. Huda, A. (2018). Analisis Pengendalian Kualitas Proses Pengelasan (Welding) dengan Pendekatan Six Sigma pada Proyek PT. XYZ. Jurnal Wacana Ekonomi, 17(2). https://doi.org/10.52434/jwe.v17i2.295 (TeePublic)
7. Ihsan, M., & Abi. (2026). Analysis of LPG Tank Defect Control Using the Six Sigma Method at PT. Metal Hitech Engineering. Al Tijarah, 11(2). https://doi.org/10.21111/at.v11i2.15682 (Darussalam Journal Online)
8. Ikhsan, M. F., Pusporini, P., & Rizqi, A. W. (2022). Analisis Pengendalian Kualitas Produk Flat Bar dengan Metode Six Sigma pada PT. Jatim Taman Steel. JUSTI (Jurnal Sistem dan Teknik Industri), 2(3). https://doi.org/10.30587/justicb.v2i3.3897 (Journal of UMG)
9. Kifta, D. A., & Munzir, T. (2022). Analisis Defect Rate Pengelasan dan Penanggulangannya dengan Metode Six Sigma di PT. Profab Indonesia. DIMENSI, 7(1), 162–174. (Jurnal UTB)
10. Nugraha, G. A., Sukanta, & Ubaidilah. (2022). Analisis Pengendalian Kualitas Produk Cacat pada Part ARB Menggunakan Six Sigma dengan Konsep DMAIC. Jurnal Ilmiah Wahana Pendidikan, 8(13), 140–148. https://doi.org/10.5281/zenodo.6961496 (Jurnal UTB)
11. Purba, H. H., Saryanto, & Trimarjoko, A. (2020). Improve Quality Remanufacturing Welding and Machining Process in Indonesia Using Six Sigma Methods. Journal Européen des Systèmes Automatisés, 53(3), 395–402. https://doi.org/10.18280/jesa.530308 (ResearchGate)
12. Ridwan, A., Cundara, N., & Sanusi. (2026). Analisis dan Improvement Kualitas Pengelasan Berdasarkan Rejection Rate Hasil NDT Ultrasonic Testing Menggunakan Metode Six Sigma. Jurnal Industri Kreatif (JIK), 10(1). https://doi.org/10.36352/jik.v10i01.1396 (OJS LPPM UIS)
13. Saidatuningtyas, I., & Rizal, M. A. (2023). Analisis Pengendalian Kualitas Produk Konstruksi Baja untuk Jembatan Menggunakan Metode Six Sigma DMAIC di Pabrik Fabrikasi Baja. Jurnal Teknologi dan Manajemen, 21(2), 75–84. https://doi.org/10.52330/jtm.v21i2.110 (Jurnal STMI)
14. Wicaksono, R. A., Momon, A., Wahyudin, Malik, F. A., & Setyanto, M. U. A. (2026). Analisis Pengendalian Kualitas Produk Cacat Menggunakan Metode Six Sigma dengan Konsep DMAIC di PT. PQR. Industrika: Jurnal Ilmiah Teknik Industri, 10(1). https://doi.org/10.37090/s4abxz34 (Jurnal UTB)
15. Yuliani, D., & Prasetyo, H. (2023). Implementasi Metode Six Sigma DMAIC dalam Pengendalian Kualitas Produk Manufaktur. Jurnal Teknik Industri Indonesia, 14(2), 101–110.