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Welding Quality Control Using The Sqc (Statistical Quality Control) Method In An Effort To Minimize The Occurrence Of Rejects At Pt.XYZ

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***Abstract**. PT. XYZ is an international company operating in the energy sector, especially oil and gas, with a focus on fabrication and construction activities for large-scale projects. One of the main production processes that is very influential is welding. To ensure welding quality, PT. XYZ uses the Non-Destructive Testing – Ultrasonic Testing (NDT-UT) method. However, during the inspection process, problems are often found in the form of rejects due to defects that do not meet welding quality standards. Some types of defects detected include LOF (Lack of Fusion), LOP (Lack of Penetration), and ESI (Excessive Spatter Inclusion). This research aims to determine the percentage of the most dominant welding defects, identify factors that cause defects, and provide recommendations for improvements to improve welding quality. The method used is Statistical Quality Control (SQC) with the help of tools such as check sheets, histograms, Pareto diagrams, scatter diagrams, control charts and fishbone diagrams. Based on the data collected, a LOF defect of 5,434 mm was found, an ESI defect of 1,990 mm, and an LOP defect of 1,030 mm. SQC analysis shows that the dominant defect is LOF with a percentage of 64%. The main causal factors come from methods, humans, machines and materials. Therefore, companies need to make improvements and developments to reduce product defects so that they can improve welding quality.*

***Keywords** Defect, Quality Control, Statistical Quality Control (SQC), Welding.*

1. INTRODUCTION

Welding is an important and inseparable part of the development of technology and industrial development. Almost every industrial development that uses metal involves a welding process. Therefore, a good quality welding joint is needed. This has an impact on determining quality (Quality Assurance) and ensuring quality (Quality Control). The quality of products or goods is a very important factor and is a key factor in business success and business competitiveness, so that to increase the value of the company's products, it is required to improve quality (Mubarok & Machfuroh, 2024).

PT. XYZ is an international company that provides services in the energy sector, especially oil and gas. PT. XYZ focuses on fabrication and construction activities for large projects. The project currently being carried out by PT. XYZ is the Neptun Deep project. The Neptun Deep project is a project that combines deepwater natural gas reservoirs in the Domino field with shallow water natural gas reservoirs in the Pelican South field. This project creates a platform. One of the most influential production processes is welding. To see the quality of PT. XYZ uses the Non Destructive Testing – Ultrasonic Testing (NDT-UT) method. However, when conducting inspections, there are often reject obstacles due to

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defects that do not meet welding quality standards, resulting in waste to make repairs which result in additional costs for rework, longer production times and ultimately impact client satisfaction.

In the problems faced by PT.XYZ, the best solution is to use the Statistical Quality Control (SQC) method. Statistical Quality Control (SQC) is a quality control method that uses a statistical approach. Its main purpose is to identify specific causes of variation or errors in the process through data analysis. With this approach, SQC functions as a very effective tool to ensure that products meet predetermined specifications, from the initial stage to the end of the production cycle (Oktavia & Herwanto, 2021). Therefore, this study aims to determine the factors that cause defects in an effort to minimize rejects using the Statistical Quality Control (SQC) method. The Statistical Quality Control (SQC) method aims to continuously improve the company's process competence in carrying out production. This approach is expected to gradually improve product quality until it reaches a zero failure rate (Zero Defect).

2. LITERATURE REVIEW

A. Quality

Quality is the consumer's perception of the condition or state of a product. Products with good quality are able to meet or even exceed consumer expectations. By providing quality products, companies can build consumer trust, increase the number of customers who like the product, and retain existing consumers. Quality covers various aspects, including the product itself, the workforce, the production process and the work environment. In addition, quality is dynamic, meaning that current quality standards may be considered inadequate in the future as consumer needs and expectations change (Hendrawan et al., 2020). Good quality comes from an optimal process and in accordance with established standards. Quality can be interpreted as consistency in improvement or enhancement, as well as reducing variations in the characteristics of a product (both goods and services), so that the product is able to meet the specified specifications and increase customer satisfaction (Fatah & Al-Faritsy, 2021).

B. Quality Control

Quality control is a process that aims to ensure that the products produced are in accordance with the expected standards. If a product is found that does not meet the standards, corrective actions in the production process will be taken to ensure the best quality. The main purpose of quality control is to improve the product through continuous monitoring of production results, so that the production process can run according to the established standards, and product quality continues to improve (Supardi & Dharmanto, 2020). The principle of quality control is an effort to achieve and improve the production process through inspections that are carried out continuously. The results of this inspection are used as a basis for analysis, thus producing useful information to control and improve the quality of the process and products. Thus, the production process can meet the product specifications expected by customers (Lestari & Purwatmini, 2021).

C. Weld Defect

Weld Defect or welding defect is a condition where there is damage or imperfection on the weld surface that can reduce the quality and strength of the weld joint. This defect occurs due to welding results that do not meet the acceptance requirements as stated in standards such as ASME IX, AWS, API, or ASTM. The cause of welding defects can come from improper welding procedures, inadequate preparation, or the use of equipment and supporting materials (consumables) that do not comply with standards. According to Achmadi, welding defects are divided into two types, namely:

1. Internal welding defects: Defects that are in the weld and are not visible from the surface.
2. Visual welding defects: Defects that can be seen directly on the weld surface.

(Yunianto & Wicaksana, 2023)

D. Ultrasonic Testing (UT)

Ultrasonic testing is one of the Non-Destructive Testing (NDT) methods that is often used in the manufacturing process to detect defects, cracks, or other discontinuities without damaging the material. This method works by emitting high-frequency sound waves, namely between 0.25 and 10 MHz, into the material through a predictable path. Ultrasonic testing tools utilize the principle of ultrasonic waves produced by the probe. These waves appear due to the conversion of electrical energy into mechanical energy by the transducer through the piezoelectric effect. This piezoelectric effect is reversible and useful for producing the desired frequency (Putra, Rizki Firmanzah Wardani, 2023).

Statistical Quality Control (SQC)

E. Statistical Quality Control (SQC) is a system designed to maintain uniform production quality standards at minimum cost, while supporting the operational efficiency of the company. This method involves the use of statistical techniques to collect and analyze data to determine and monitor the quality of production results efficiently. With the implementation of statistical-based quality control, it is expected that there will be a significant increase in production quality. In the context of quality control, SQC aims to ensure that the products produced are in accordance with predetermined standards. In addition, SQC functions as a problem-solving technique used to monitor, control, analyze, manage, and improve products using statistical methods, so that it can make a real contribution to improving production quality (Nazia et al., 2023). The application of the Statistical Quality Control (SQC) method requires a comprehensive approach in the production process. This method includes statistical quality control, both for data in the form of variables and attributes (Saputra & Nugroho, 2023).

3. METHODS

This research was conducted at PT. XYZ by applying the Statistical Quality Control (SQC) method through six stages, namely: checking with checksheets, analysis with histograms, analysis with pareto diagrams, analysis with scatter diagrams, analysis with control charts and analysis with fishbone diagrams.

A. Data Collection

In this study, the data collected consisted of primary data and secondary data.

1) Data Primer

   Primary data was taken from direct interviews with the NDT section of the Quality Department.

2) Data Seconds

   Secondary data is taken from Ultrasonic Testing (UT) reject data for plate welding. The following is reject data from July - October 2024.

Table 3. 1 Welding Plate Result Reject Data

No	Date	Number of Samples (mm)	Reject Type (mm)			Number of Rejects (mm)
			LOF Defect	LOP Defect	ESI Defect	
1	9-Jul-24	487	0	180	0	180
2	11-Jul-24	2773	90	0	0	90
3	16-Jul-24	2781	90	0	0	90
4	18-Jul-24	5545	560	0	800	1360
5	23-Jul-24	549	0	60	0	60
6	31-Jul-24	2446	230	0	0	230
7	3-Aug-24	1214	0	110	0	110
8	7-Aug-24	5813	0	0	230	230
9	8-Aug-24	4677	0	0	110	110
10	9-Aug-24	462	0	70	0	70
11	14-Aug-24	462	400	0	0	400
12	15-Aug-24	1240	140	0	0	140

No	Date	Number of Samples (mm)	Reject Type (mm)			Number of Rejects (mm)
			LOF Defect	LOP Defect	ESI Defect	
13	16-Aug-24	1240	140	0	0	140
14	19-Aug-24	2290	600	520	200	1320
15	26-Aug-24	948	500	60	0	560
16	29-Aug-24	3687	893	0	0	893
17	4-Sep-24	700	430	0	0	430
18	6-Sep-24	1880	30	30	0	60
19	9-Sep-24	300	60	0	0	60
20	14-Sep-24	300	40	0	0	40
21	17-Sep-24	1040	0	0	300	300
22	21-Sep-24	1500	1070	0	0	1070
23	2-Oct-24	5358	0	0	350	350
24	8-Oct-24	300	61	0	0	61
25	12-Oct-24	650	100	0	0	100

B. Defect Type Overview

a. LOF (Lack of Fusion) Defect

LOF defect or lack of fusion is a type of defect in the welding process that occurs when the base metal and filler metal do not fuse perfectly along the weld line or in certain areas.

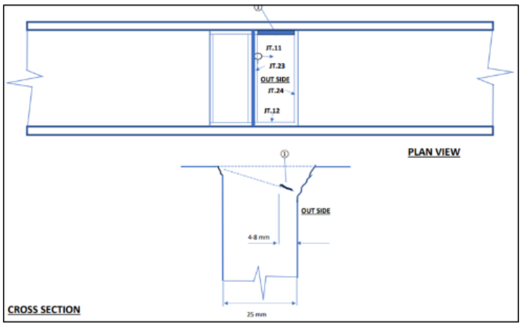


Figure 3. 1 Examples of LOF Defects (Lack of Fusion)

b. LOP (Lack of Penetration) Defect

LOP or lack of penetration defect is a type of defect in the welding process where the filler metal fails to fully penetrate into the base metal at the welded joint.

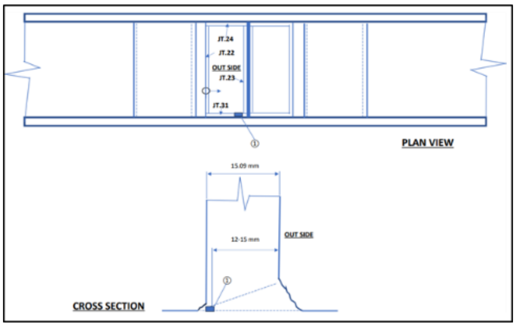


Figure 3. 2 Example of LOP (Lack of Penetration) Defect

c. ESI (Excessive Spatter Inclusion) Defect

ESI defects are a type of welding defect in which slag or remnants of the protective material on the electrode are trapped in or between the layers of weld metal. This slag is not completely burned or melted during the welding process, thus preventing a perfect bond between the filler metal and the base metal.

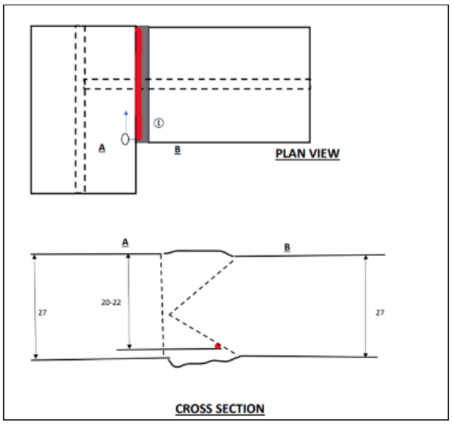


Figure 3. 3 Contoh Cacat ESI (Excessive Spatter Inclusion)

Source: NDT Quality Department PT.XYZ (2024)

4. RESULTS AND DISCUSSION

A. Statistical Quality Control (SQC)

No	Date	Number of Samples (mm)	Reject Type (mm)			Number of Rejects (mm)
			LOF Defect	LOP Defect	ESI Defect	
1	9-Jul-24	487	0	180	0	180
2	11-Jul-24	2773	90	0	0	90
3	16-Jul-24	2781	90	0	0	90
4	18-Jul-24	5545	560	0	800	1360
5	23-Jul-24	549	0	60	0	60
6	31-Jul-24	2446	230	0	0	230
7	3-Aug-24	1214	0	110	0	110
8	7-Aug-24	5813	0	0	230	230
9	8-Aug-24	4677	0	0	110	110
10	9-Aug-24	462	0	70	0	70
11	14-Aug-24	462	400	0	0	400
12	15-Aug-24	1240	140	0	0	140
13	16-Aug-24	1240	140	0	0	140
14	19-Aug-24	2290	600	520	200	1320
15	26-Aug-24	948	500	60	0	560
16	29-Aug-24	3687	893	0	0	893
17	4-Sep-24	700	430	0	0	430
18	6-Sep-24	1880	30	30	0	60
19	9-Sep-24	300	60	0	0	60
20	14-Sep-24	300	40	0	0	40
21	17-Sep-24	1040	0	0	300	300

No	Date	Number of Samples (mm)	Reject Type (mm)			Number of Rejects (mm)
			LOF Defect	LOP Defect	ESI Defect	
22	21-Sep-24	1500	1070	0	0	1070
23	2-Oct-24	5358	0	0	350	350
24	8-Oct-24	300	61	0	0	61
25	12-Oct-24	650	100	0	0	100
Total		**48642**	**5434**	**1030**	**1990**	**8454**

1) Checksheet

Checksheet or check sheet is a tool designed to facilitate the data collection process. In many cases, recording is done to make it easier to see data patterns when data collection.

Table 4. 1 Welding Plate Result Cheeksheet

Based on the table above, it is known that the types of rejects with a total sample of 48.642 mm are LOF (Lack of Fusion) defects with a total of 5.434 mm, LOP (Lack of Penetration) defects with a total of 1.030 mm and ESI (Excessive Spatter Inclusion) defects with a total of 1.990 mm, so that the total number of welding defects in July - October 2024 is 8.458.

2) Histogram

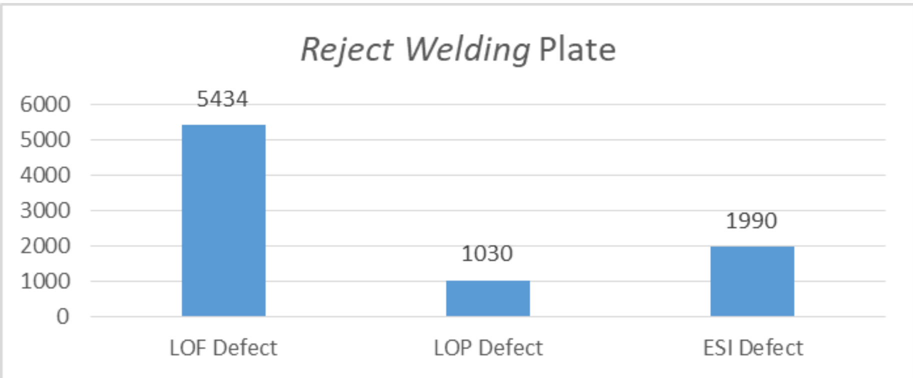


Figure 4. 1 Reject Welding Plate Histogram

Based on the image above, it can be seen that the position with the highest defect is the LOF (Lack of Fusion) defect of 5.434 mm, then the ESI (Excessive Spatter Inclusion) defect of 1.990 mm and the LOP (Lack of Penetration) defect of 1.030 mm.

3) Pareto Diagram

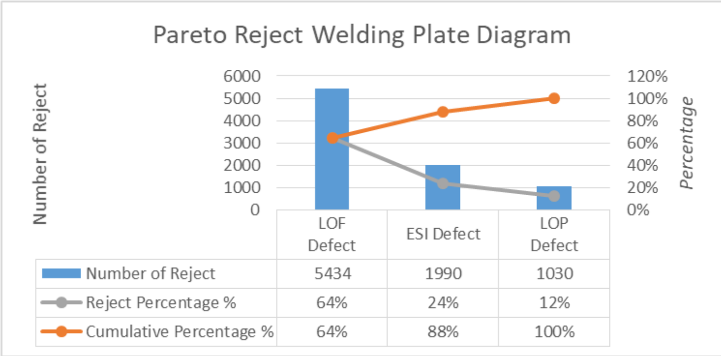
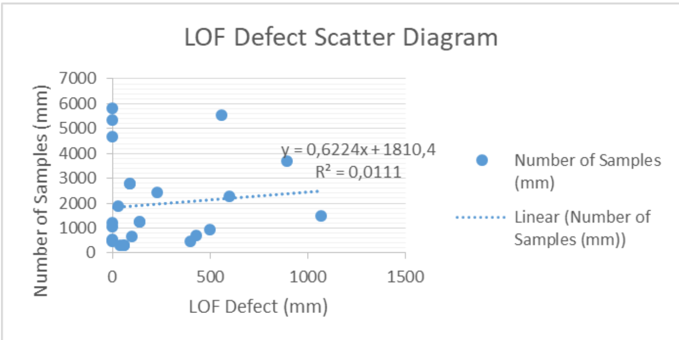
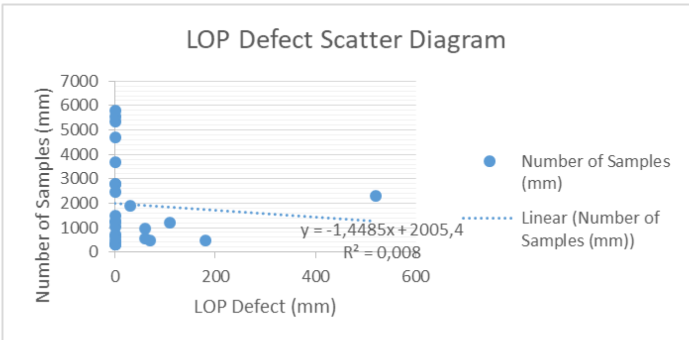


Figure 4. 2 Pareto Reject Welding Plate Diagram

Based on the image above, it can be seen that the LOF (Lack of Fusion) defect of 5,434 mm has a percentage of 64% with a cumulative percentage of 64%, the ESI (Excessive Spatter Inclusion) defect of 1,990 mm with a percentage of 24% and a cumulative percentage of 88% and finally there is the LOP (Lack of Penetration) defect of 1,030 mm with a percentage of 12% and a cumulative percentage of 100%.

4) Scatter Diagram





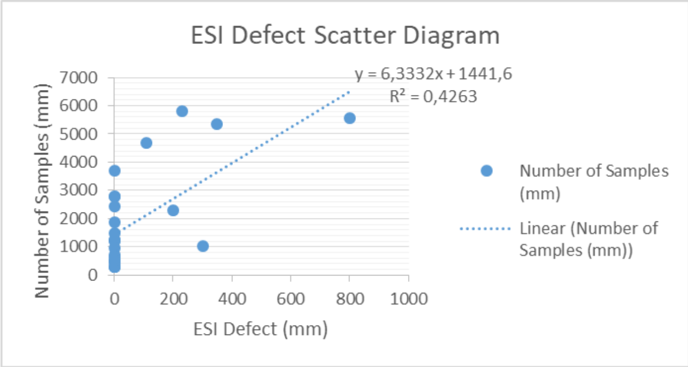
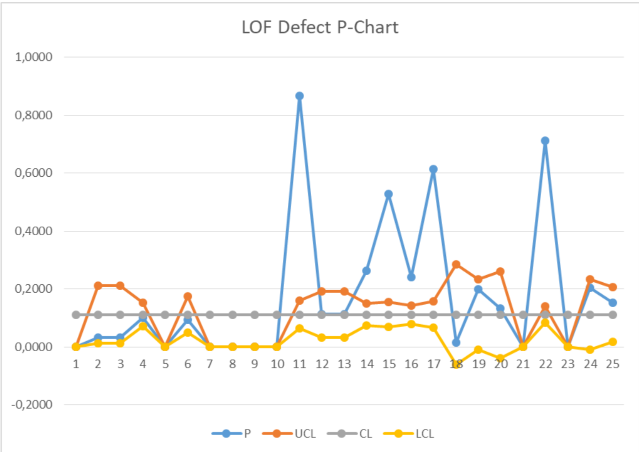
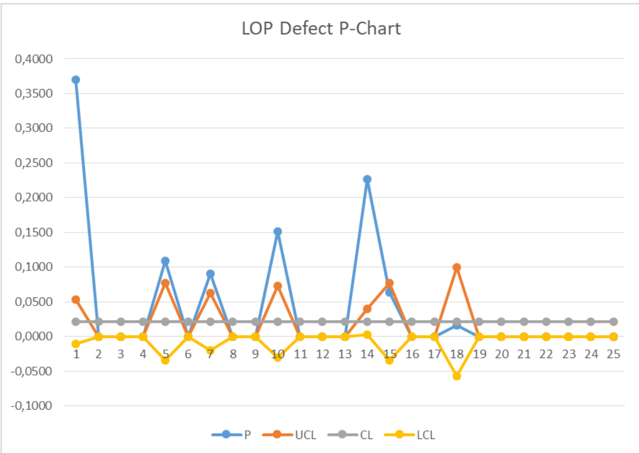


Figure 4. 3 Scatter Diagram

Based on the image above, the scatter diagram results of LOF, LOP and ESI defects are obtained with variable X being the value of the type of defect and variable Y being the number of welding samples. It can be seen that every time a welding process occurs, LOF and ESI defects also increase, but do not affect LOP defects because there is a negative relationship. So it can be concluded that the relationship between variables X and Y on LOF and ESI defects is directly proportional while on LOF defects it is inversely proportional.

5) Control Chart





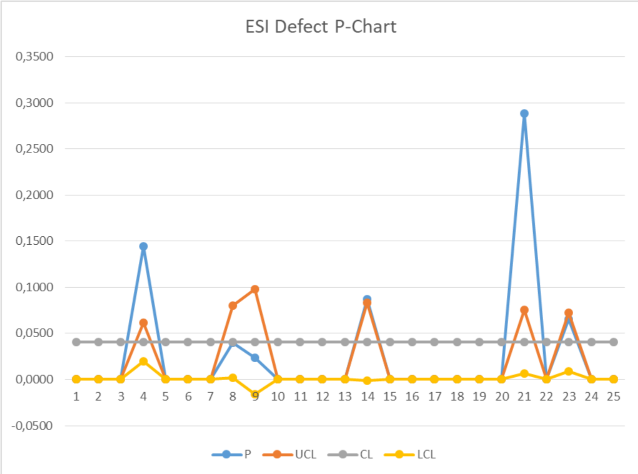


Figure 4. 4 Defect Control Chart

Based on the results of the P-Chart control map above, it can be seen that there are 6 points in the LOF defect, 5 points in the LOP defect and 2 points in the ESI defect whose proportion values are outside the upper limit (UCL), lower limit (LCL) and center line value (CL) of 0,1117, 0,0212 and 0,0409. So it can be said that the data is still not under control.

6) Fishbone Diagram

From the results of all the analyses above, it can be shown that the most dominant level of defects occurs in the LOF (Lack of Fusion) type of defect because it has the largest number, namely 5.434 mm. Next, identify the type of LOF defect using a cause-and-effect diagram as shown in the following image:

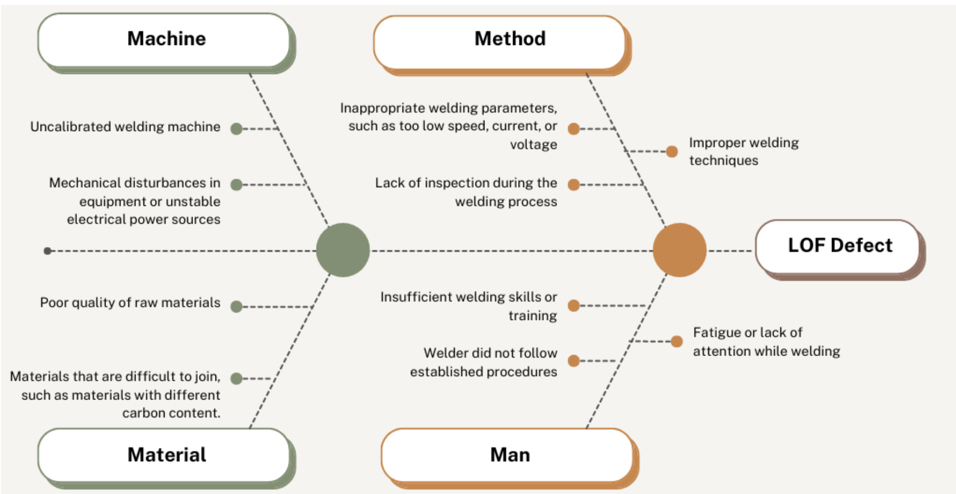


Figure 4. 5 Fishbone Diagram LOF Defect

In the fishbone diagram of LOF (Lack of Fusion) defects, there are 4 factors that cause defects. First, the method factor is inappropriate welding parameters, lack of inspection during the welding process and improper welding techniques. Second, the human factor is lack of welding skills or training, the welder does not follow the established procedures and fatigue or lack of attention when welding. Third, the machine factor is an uncalibrated welding machine and mechanical interference on the equipment or unstable power sources. Fourth, the material factor is poor quality of the base material and materials that are difficult to combine such as materials with different carbon content.

B. Improvement Proposal

Based on the fishbone diagram of the LOF (Lack of Fusion) defect in the plate welding results caused by many different factors, a proposal for improvement can be made. The following is a proposal for improvement in an effort to minimize the occurrence of rejects in the welding results:

Cause of Defect		**Improvement Proposal**
Method	Inappropriate welding parameters, such as too low speed, current or voltage	Optimize welding parameters (speed, current, and voltage) to achieve good fusion. These parameters can be adjusted based on the material used and its thickness
	Lack of inspection during the welding process	Increase inspections during the welding process to detect potential lack of fusion as early as possible
	Improper welding techniques	Provides guidance on proper welding techniques, including ideal positions, angles and speeds to avoid errors
Man	Insufficient welding skills or training	Provide specialized training for welders in appropriate welding techniques and required parameters
	Welder did not follow established procedures	Ensure welders always understand and follow procedures
	Fatigue or lack of attention while welding	Arrange work schedules that avoid fatigue, as well as provide an ergonomic work environment to reduce errors due to fatigue
Machine	Uncalibrated welding machine	Perform calibration on welding equipment periodically
	Mechanical disturbances in equipment or unstable electrical power sources	Ensure a stable power supply to avoid interference that could affect welding quality
Material	Poor quality of raw materials	Ensure material cleanliness from contaminants, oxidation, or dirt
	Materials that are difficult to join, such as materials with different carbon content	Perform material testing to ensure its characteristics meet welding requirements

5. CONCLUSION

Berdasarkan hasil inspeksi NDT *Ultrasonic Testing* (UT) yang dilakukan di PT. XYZ, didapatkan adanya indikasi cacat yaitu LOF *(Lack of Fusion),* LOP *(Lack of*

Penetration) dan ESI *(Excessive Spatter Inclusion)*. Pada metode *Statistical Quality Control* (SQC) didapatkan bahwa jenis cacat paling dominan dilihat dari persentase kumulatif adalah cacat LOF sebesar (64%), lalu cacat ESI sebesar (24%) dan cacat ESI sebesar (12%). Sehingga dapat disimpulkan jenis cacat paling besar adalah cacat LOF. Adapun penyebab terjadinya cacat LOF pada pengelasan plate yaitu karena faktor metode, manusia, mesin dan material. Lalu diberikan usulan perbaikan sesuai dengan faktor-faktor tersebut. Sehingga hasil dari penelitian ini dapat dijadikan panduan dalam pengendalian kualitas pengelasan di PT. XYZ agar ketiga jenis cacat yang terjadi dapat dikendalikan.

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