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Analysis of Product Defect Reduction in Tubular Heaters Using Define, Measure, Analyze, Improve, and Control (DMAIC) Method

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Abstract
This study aims to analyze the causes of defects in tubular heater products at PT Usaha Saudara Mandiri using quantitative data from total production and defects from January to December 2022. The sampling technique involved observation and interviews. The DMAIC method uses tools such as Control Charts, Pareto Chart, and Fishbone Diagram to improve product quality, identify the root causes of defects, and optimize the production process. The analysis results showed a total of 1,297 defective products out of 11,213 produced, with the most dominant defects occurring in February up to December 2022. Incorrect Marking ID was the main type of defect, accounting for 47%, followed by Heater Short Body (10%) and NG Display (9%). The DPMO (defect per million opportunity) was 16,502 with a sigma level of 3.63. The proposed improvements are focused on addressing the root causes with RPN values from highest to lowest, namely use of inappropriate bending molds, level of operator fatigue and the machine performance has declined. The result of this research recommends providing a request form and creating bending molds to address the issue of incomplete mold availability, along with a daily machine condition checklist, and providing a routine maintenance form to monitor and maintain machine performance. Additionally, it is necessary to create a briefing schedule and conduct regular supervision by the PIC of the tubular heater to address operator inattention.

Keywords: *Defect; DMAIC; DPMO*

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I. INTRODUCTION

The number of medium and large-scale manufacturing companies in 2022 reached approximately 29 thousand businesses or companies (BPS 2022). The manufacturing industry continues to grow in Indonesia, ranging from small to medium and large scales. With the growth of the manufacturing industry in Indonesia, it will inevitably increase competition in the market. As a result, the tight competition in Indonesia's manufacturing sector requires companies to create high-quality products to compete with other competitors.

PT Usaha Saudara Mandiri is a manufacturing company that produces heating elements, including Tubular Heaters, Thermocouples, Cartridge Nozzles, and Band Heaters. In reality, defects are still commonly found in the tubular heater products.

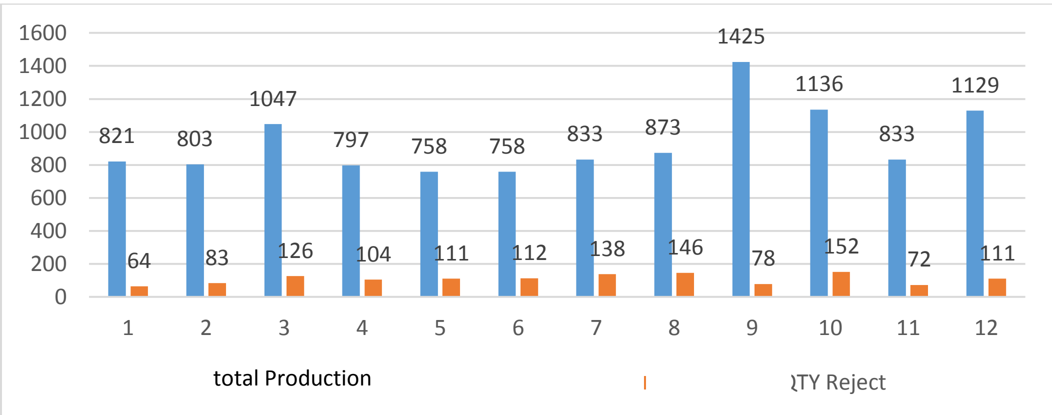

Figure 1. Total Production and Defect Tubular Heater

It can be seen that for the tubular heater product, the total defects from January 2022 to December 2022 amounted to 1,295 defective units out of a total of 11,213 parts produced. The defect tolerance level set by the company is approximately 5%. However, based on the figure, the number of defects in the tubular heaters exceeds the tolerance level set by the company, amounting to approximately 560.65 units. This occurred throughout the period from January 2022 to December 2022.

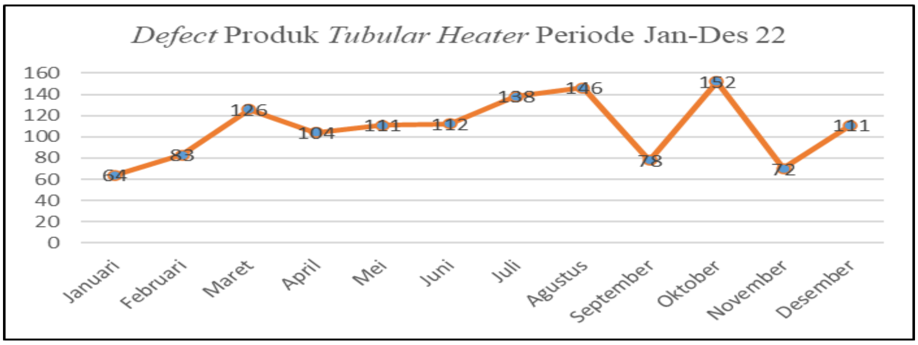

Figure 2. Total Production and Defect Tubular Heater

In an effort to reduce the product defect rate, one of the methods used to decrease the number of defects is the DMAIC method (Define, Measure, Analyze, Improve, Control). DMAIC is a comprehensive approach for quality control and improvement, as it starts with identifying the problem, continues through to control, and includes recommendations for improvement (Caesaron et al., 2015). With the number of defects in the tubular heater products exceeding the tolerance limit set by PT Usaha Saudara Mandiri (PT USM), this study will identify the root causes of the issue. This will be done through the application of the DMAIC method, with the aim of providing recommendations to reduce the number of defects in the tubular heater products at PT USM.

Based on the issues identified, it is necessary to measure efforts aimed at improving quality and production efficiency, particularly for the tubular heater products. Several key aspects require in-depth analysis. First, there is a need to determine the sigma level and Defects Per Million Opportunities (DPMO) values for the period from January to December 2022. Determining these values will provide an overview of production quality and the defect rate, which are key indicators in measuring the performance of the production process.

Next, it is important to identify the factors that cause defects in the tubular heater products. This identification is not only crucial for understanding the underlying causes of the issues but also for developing effective strategies to address quality problems. A deep understanding of the causes of defects will be highly beneficial in designing appropriate interventions to improve production quality.

Finally, there is a need to develop concrete and practical improvement proposals to reduce the number of defects occurring in the tubular heater products. These improvement proposals should be result-oriented and practical to implement, considering the resource limitations often faced by SMEs. These improvement steps will not only contribute to the enhancement of product quality but also to the reputation and customer trust in the SME's products.

II. LITERATURE REVIEW

Quality

The Indonesian National Standard (SNI 19-8402-1991) as cited in Ariani, (2019), defines quality as the overall attributes and characteristics of a product or service whose capabilities can satisfy needs, both explicitly stated and implied. The term "needs" is understood as the specifications listed in the contract as well as the criteria that must be defined in advance. The quality of a good product is determined through quality dimensions. According to Gaspersz (2008), the quality dimensions include 8 dimensions, which consist of :

1. Performance refers to how well a product meets its primary function or operational characteristics.
2. Feature is a unique characteristic of the product that differentiates it from other products and creates a positive impression for the customer.
3. Reliability is the level of customer trust in the product's performance.
4. Conformance to Standards measures how well the product complies with specific requirements or standards, as well as how its design and operational characteristics meet the established standards.
5. Durability refers to the product's lifespan or the length of time it remains functional.
6. Serviceability refers to how easy it is to repair the product or access its components.
7. Aesthetics describes the visual appeal or beauty of the product.
8. Perception refers to the extent to which consumers are loyal to a specific brand due to its image or reputation.

Quality is a key factor considered when choosing a product. Therefore, companies, whether in manufacturing or service sectors, need to ensure that their products meet established standards. This can be achieved through continuous efforts to improve and enhance product quality during the production process. As a result, it will not only produce higher-quality products but also contribute positively to the company's productivity (Widiaswant, 2014).

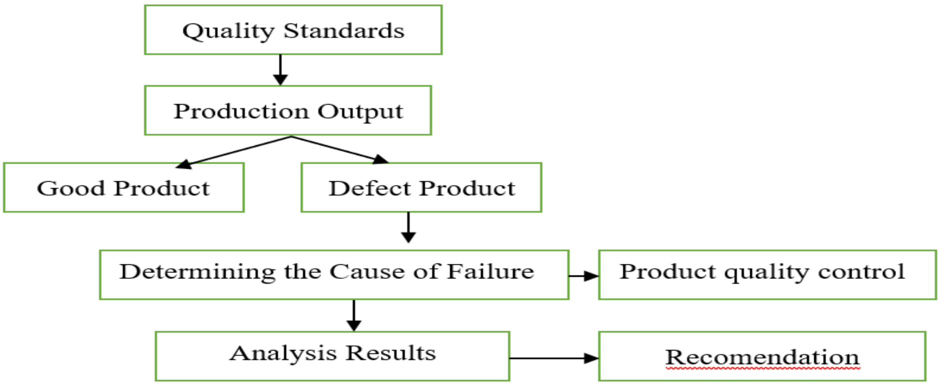

Figure 3 Quality Control Flow

Each product has quality parameters related to customer needs, known as Critical to Quality (CTQ). These parameters become variables that must be controlled and improved in efforts to enhance quality. In quality control, product specifications have tolerance limits adjusted to customer requirements. The upper limit is referred to as the Upper Specification Limit (USL), while the lower limit is referred to as the Lower Specification Limit (LSL) (Gaspersz, 2005).

Defect

A defect is a condition in which a product is considered to have failed to meet the requirements set by the company or the customer. According to Primanintyo et al. (2016), defects are categorized into several types, namely:

a Major defect: This category refers to defects with a high level of severity, commonly referred to as scrap. Products with major defects cannot undergo rework processes, and therefore must be discarded or quarantined.

b Minor defect: This category refers to defects with a low level of severity. Products with minor defects can still be repaired (reworked) to meet certain specifications..

Six Sigma

The basic concept of Six Sigma according to Gaspersz (2008) is a continuous effort to :

a) Reduce process variation in order to

b) improve process capability in producing products (goods/services) that are free from defects (zero defects - target minimum) 3,4 DPMO,

c) To provide value to customers.

According to Gaspersz (2008), Six Sigma is a vision for quality improvement aimed at achieving a target of 3.4 DPMO for every product or service transaction, and an effort toward perfection. Thus, Six Sigma is a method of quality control that represents a dramatic breakthrough in the field of quality management. In the implementation of Motorola's Six Sigma process control, there is a difference compared to the true Six Sigma process, which allows a shift in the target value (average value) by 1.5 sigma (1.5 times the maximum standard deviation), whereas the Six Sigma concept in a normal distribution does not permit any shift in the average value. This difference can be seen in the table (Gaspersz, 2008).

Table 1. The Difference Between True Six Sigma and Motorola's Six Sigma

True Six Sigma Process (Normal Distribution Centered)			Motorola's Six Sigma Process (normal Distribution Shifted 1,5-sigma)		
Specification Limit (LSL-USL)	Percentage (%)	DPMO	Specification Limit (LSL-USL)	Percentage (%)	DPMO
± 1 sigma	68,27%	317.300	± 1 sigma	30,23%	697.700
± 2 sigma	95,45%	45.500	± 2 sigma	69,13%	308.700
± 3 sigma	99,73%	2.700	± 3 sigma	93,32%	66.810

± 4 sigma	99,9973%	63	± 4 sigma	99,3790%	6.210
± 5 sigma	99,999943%	0,57	± 5 sigma	99,97670%	233
± 6 sigma	99,9999998%	0,002	± 6 sigma	99,99966%	3,4

Source : Gaspersz, 2008

The 1.5 Sigma shift value is based on research conducted by Motorola on industrial processes and systems. According to the research, no matter how good an industrial process is, it will never be 100% centered on the target value; there will always be a shift of approximately 1.5 Sigma from that value (Mastur & Aji, 2016). The concept of Six Sigma with a 1.5 Sigma shift in the normal distribution is illustrated in the figure below :

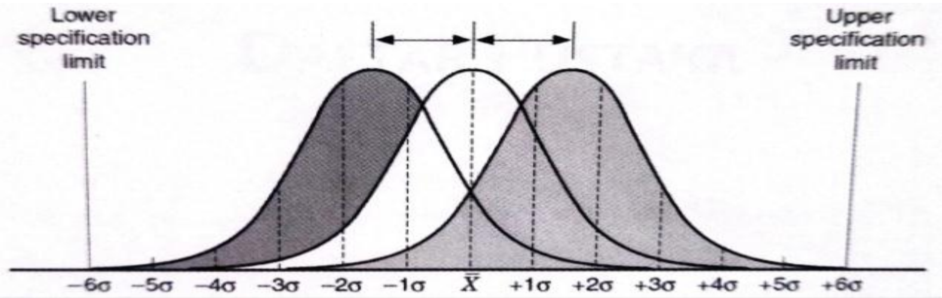

Figure 4. Motorola's Six Sigma Concept with a 1.5 Sigma Shift in the Normal Distribution

DMAIC (*Define, Measure, Analyze, Improve and Control*).

DMAIC is a method that can be used to continuously improve performance towards Six Sigma standards. The DMAIC process is carried out systematically, based on accurate information and data, with the goal of eliminating inefficient processes and striving to improve quality to meet Six Sigma standards (Gaspersz, 2008). There are five stages in the DMAIC cycle, and the steps are as follows :

1. Define. According to Harpensa et al. (2015), Define is the step to determine the goals of quality improvement activities using Six Sigma. The purpose of the Define stage is to define and explain the product that will have its quality improved. The tool used in the Define stage is:

a) Check Sheet : A check sheet is a tool used for data collection and analysis, presented in a table format. It contains data on the number of products produced and the types of defects, along with their quantities. The purpose of using a check sheet is to simplify the process of data collection and analysis (Hairiyah et al., 2019).

b) Critical to Quality (CTQ) : According to Tannady (2015), CTQ (Critical to Quality) refers to the limits, characteristics, and quality standards for the dimensions of quality that must be maintained in a product. The determination of CTQ is based on the types of defects present in a product; these defects can cause faults or have the potential to lead to product defects (Harpensa et al., 2015).

c) SIPOC Diagram : The SIPOC diagram is used to identify suppliers and their inputs into the process, the sequence of the process, the outputs of the process, and the importance of suppliers to the outputs Saludin (2016).

2. Measure. The second stage is measurement, where the production process is evaluated to identify any deviations that may occur during operations. Through these measurement results, the company can assess its performance and set the necessary improvement targets.

3. Analyze. In the implementation of DMAIC, the third step is Analyze, where an examination is conducted regarding the cause-and-effect relationship between various factors being studied to identify the key factors that need to be managed or controlled (Wijaya & Khair, 2019).

4. Improve. This step is the fourth in the DMAIC cycle. At this stage, efforts are made to improve the process, which involve developing ideas to eliminate the root causes, conducting trials, and measuring the results (Wijaya & Khair, 2019).

5. Control. The final stage in the DMAIC process is the stage to establish standardization, control, and sustain the improvements that have been implemented and enhanced over the long term, with the goal of preventing potential issues that may arise in the future (Miftahul & Revino, 2017).

III. RESEARCH METHOD

In this study, the type of research conducted is quantitative research. Descriptive quantitative research is an investigative process that uses numerical data as a tool to analyze information related to what is intended to be understood (Gupta et al., 2018). This type of research falls under the quantitative category because it involves the collection of data in the form of defect numbers and types of product defects expressed in numerical form.

Types of Data and Information

The types of data used are primary data and secondary data, as explained below:

1. Primary Data

Primary data refers to data obtained and collected through direct observation in the research area:

- Observation: Data is collected by directly observing and examining the objects to be studied. Observations are made in detail in the work area of the tubular heater product and the process of quality control checks for the tubular heater product.
- Interviews: The researcher conducts interviews with experienced individuals, especially those in the production and quality control departments, to obtain data on severity, occurrence, and detection ratings, as well as data on the causes of defects in the tubular heater product.

2. Secondary Data

Secondary data refers to data sourced from the company's own processed data. The secondary data obtained for this study includes: production data, data on the number of defects and types of defects from January to December 2022, as well as general company information.

Data Processing

The data processing is carried out using the DMAIC method, with the following summary of the DMAIC stages:

1. Define the Problem: Identify the problem that needs to be addressed, the goals to be achieved, and collect baseline data to begin the improvement project.
2. Measure Current Performance: Gather data by measuring the performance of the current process, determine relevant metrics, and create process maps to understand the steps involved.
3. Analyse the Data: Analyse the collected data to identify the root causes of the problem using statistical techniques and other analytical tools.
4. Improve the Process: Develop and test solutions to address the identified issues, then implement changes to improve process performance.
5. Control Changes: Ensure that improvements are sustained in the long term by establishing continuous monitoring, creating standard operating procedures, and training employees.

IV. RESULT

Define

1. Check Sheet for Tubular Heater Product Defects

Below is the data on the types of defects that occurred in the tubular heater product. The data below was obtained from historical data from the Quality Control department at PT USM:

Table 3: Tubular Heater Check Sheet Data

No.	Critical To Quality	Total Defect Jan-Des 2022
1	Appearance NG	115
2	Heater Short Body	150
3	Resistance Error	99
4	Low Resistance	115
5	NG Welding	101
6	Detached Terminal	107
7	Incorrect Marking ID	610
Total		1.297

2. Critical to Quality (CTQ)

Determining the CTQ points based on the types of defects that occurred in the Tubular Heater product. The types of defects are as follows:

Table 4. CTQ of Tubular Heater Product

No	Critical To Quality	Explanation
1	Appearance NG	The type of defect is observed based on the performance of the product's surface appearance, which appears rough or untidy
2	Heater Body Short	The type of defect occurs due to a short circuit in the body of the Tubular Heater
3	Resistance Error	The type of defect is observed from the occurrence of a short circuit at the terminal of the Tubular Heater
4	Low Resistance	The type of defect is observed from the very low resistance level
5	NG welding	The type of defect that occurs in welding results that are untidy
6	Detached Terminal	Detachment of the terminal from the heating component
7	Incorrect ID Marking	The type of defect observed is that the product section is uneven, causing the ID marking to be unclear or not visible

3. SIPOC Diagram *(Supplier, Input, Process, Output, and Customer).*

The SIPOC diagram is used to identify all the elements in a production process before any corrective actions are implemented. The SIPOC diagram represents the inputs and outputs of one or more processes, outlined in the form of a table. Below is the SIPOC diagram for the tubular heater manufacturing process in this study.

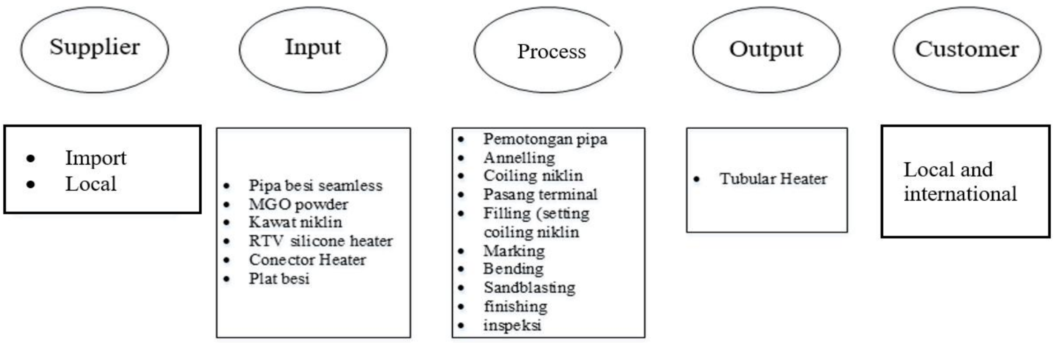

Figure 5. SIPOC Diagram

Based on the SIPOC diagram in Figure 5, it is possible to understand and identify the process from the supplier to the customer stage of the tubular heater product. Below are the results of the SIPOC diagram:

- Supplier

The raw materials used as the initial step in the tubular heater manufacturing process are sourced from various suppliers in Indonesia, with some materials imported, such as MGO powder (magnesium oxide) and silicone rubber.

- Input

The main component for proceeding with the tubular heater manufacturing process is the raw material. The primary raw materials for making the tubular heater are seamless steel pipes, MGO powder, nichrome wire, RTV silicone heat resistance, heat connectors, and steel plates. All raw materials undergo inspection once they are retrieved from the raw material storage warehouse. For materials imported from abroad, they are quarantined in a special warehouse located in Cikarang.

- *Process*

In the process stage, there are 10 steps in the manufacturing of the tubular heater: (1) Pipe Cutting; (2) Nichrome Coiling; (3) Terminating; (4) Filling with MGO Powder; (5) Swagging; (6) Annealing; (7) Bending; (8) Installing the heater connector and trans fittings; (9) Marking; (10) Inspection.

- *Output*

The output produced is the tubular heater product that has been customized to meet the physical characteristics specified by the customer.

- *Customer*

The products that have been inspected will then be packed for immediate shipment to the customer or stored if there is a special request from the customer.

Measure

The measure stage discusses the results of measurements and calculations of DPMO (Defects Per Million Opportunities) and Sigma values, as well as the control limits for defects occurring in the tubular heater product, based on data from the check sheet using the P-chart.

1. DPMO and Sigma Quality Level

DPMO is a measure of failure in the Six Sigma quality improvement program, indicating failures per million opportunities. Based on the previous table, data was obtained to calculate the DPMO value and the Sigma value.

2. The concept of control charts.

Measurement and the creation of the P-chart are conducted to determine whether the ongoing production process of the tubular heater product is still under control (within control limits) or not. The choice to use the P-chart is because it is suitable for controlling defects in production results with attribute defect data and varying or inconsistent production capacity, specifically in the tubular heater production at PT. Usaha Saudara Mandiri during the period of January 2022 – December 2022. Below are the measurements and calculations using the control chart :

Table 5: P-Chart Calculation

Month	Total Production	Defect	Proportion of Defect	UCL	CL	LCL
January	821	64	0.07	0.1484	0.115	0.0815
February	803	83	0.103	0.1487	0.115	0.0812
March	1.047	126	0.120	0.1445	0.115	0.0854
April	797	104	0.130	0.1489	0.115	0.0810
May	758	111	0.146	0.1497	0.115	0.0802
June	758	112	0,147	0.1497	0.115	0.0802
July	833	138	0.165	0.1481	0.115	0.0818
August	873	146	0.167	0.1473	0.115	0.0826
September	1.425	78	0.057	0.1403	0.115	0.0896
October	1.136	152	0.133	0.1433	0.115	0.0866
November	833	72	0.086	0.1481	0.115	0.0818
December	1.129	111	0.98	0.1434	0.115	0.0865
TOTAL	11.123	1.297				

Source : Data Proceed, (2022)

Here are the results for the P-chart data on tubular heater production during the period from January to December 2022 :

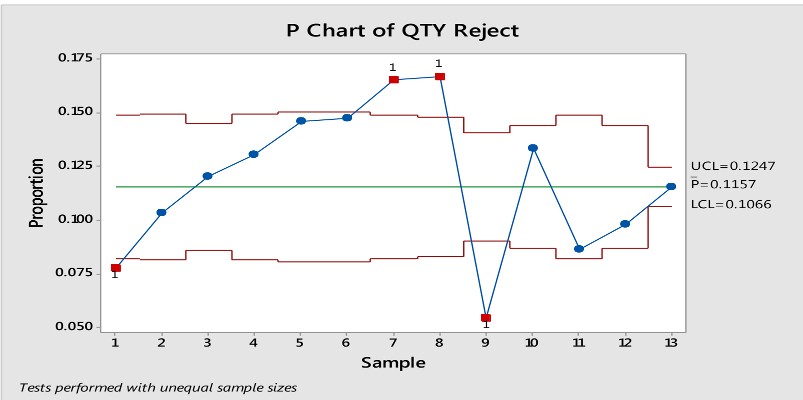

Figure 6. P- Control Chart
(Source : Data Proceed, (2022)

Based on the chart above, it can be seen that in the production process of the tubular heater product, there are 4 data points that fall outside the upper and lower control limits. These data points outside the control limits occurred in January, July, August, and September 2022. Below are the results of the calculations after elimination, as shown in Table 6 :

Table 6. Elimination Calculation of the P-Chart

Mounth	Production Quantity	Defect	Defect Proportion	UCL	CL	LCL
February	803	83	0,103	0,1487	0,115	0,0812
March	1.047	126	0,120	0,1445	0,115	0,0854
April	797	104	0,130	0,1489	0,115	0,0810
May	758	111	0,146	0,1497	0,115	0,0802
June	758	112	0,147	0,1497	0,115	0,0802
October	1.136	152	0,133	0,1433	0,115	0,0866
November	833	72	0,086	0,1481	0,115	0,0818
Desember	1.129	111	0,098	0,1434	0,115	0,0865
TOTAL	7.261	869				

In Table 6, the calculation results for the defect proportion data, CL value, UCL value, and LCL value are presented after eliminating the data points outside the control limits. These are then plotted on a control chart (P Chart) to determine whether the tubular heater production process is within control or not. Below is the P-Chart after elimination :

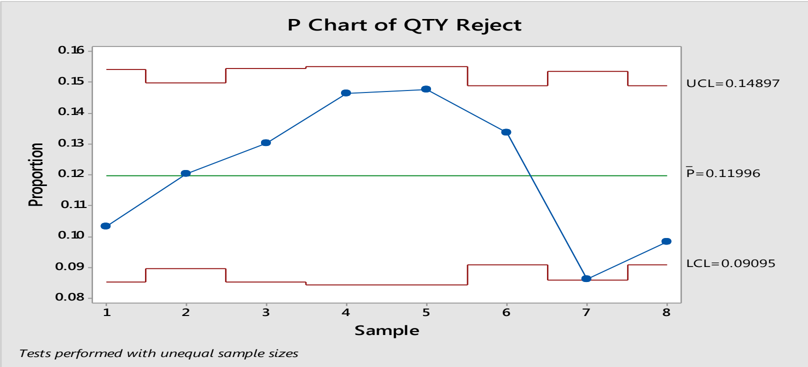

Figure 7. Eliminated P-Chart
(Source : Data Proceed, (2022)

Analyze

1. Identifying the Most Dominant Type of Defect

From the P-Chart, it is observed that in January, July, August, and September 2022, the process was out of control. Therefore, to identify the most frequent defect type during the period from January 2022 to December 2022, the data was processed using a Pareto chart :

Table 1. Pareto Chart Calculation

Type of Defect	Total Defect	Presentage (%)	Cumulative Percentage (%)
Incorrect Marking ID	610	47	47
Heater Short Body	150	12	59
Marking NG	115	9	68
Low resistance.	115	9	77
NG Welding	107	8	85
Detached Terminal	101	8	93
Resistance error	99	7	100
Total	1.297	100	

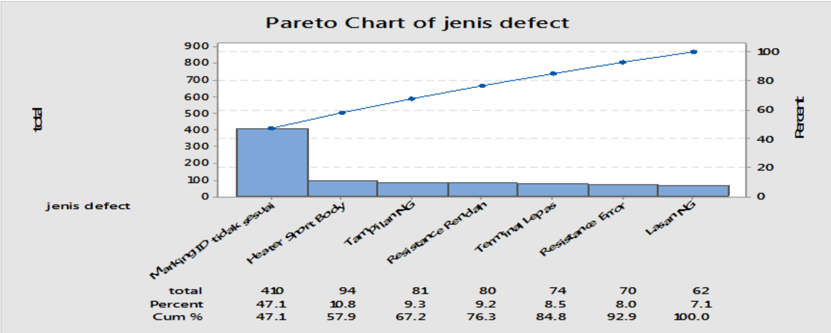

Figure 8. Pareto *Defect* Tubular Heater Diagram

Based on the Pareto diagram shown above, it can be observed that the most dominant defect types during February, March, April, May, June, October, November, and December of 2022 were Marking ID Not Matching, with a percentage of 47%, followed by Heater Short Body at 10%, Marking NG at 9%, and so on.

2. Analysis of the Most Dominant Defect Type

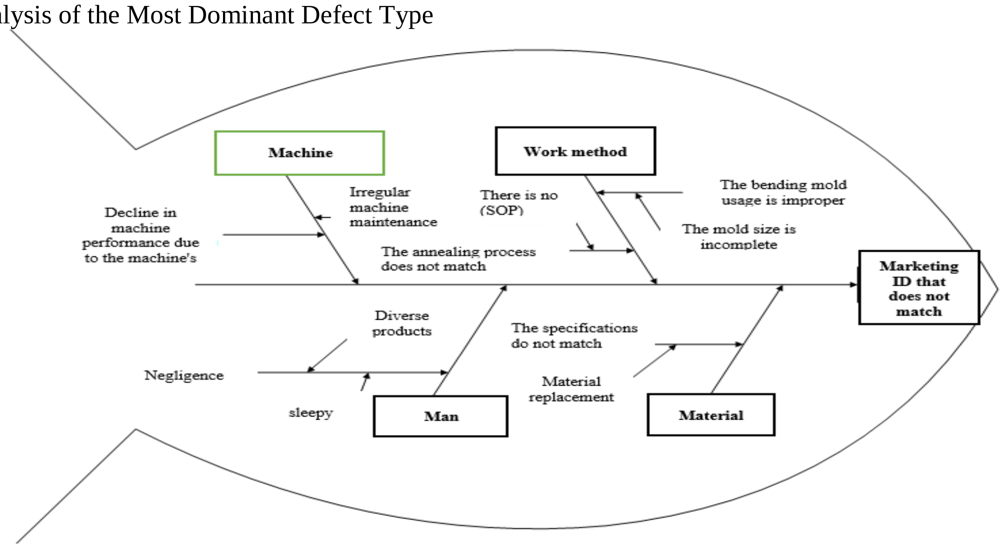

Figure 9. Fishbone

The analysis of the factors causing the defect of mismatched ID marking, as shown in the fishbone diagram above, can be conducted through production factors, including people, machines, materials, and work methods. Each of these factors has a main cause and a root cause, which will then be further analyzed using FMEA analysis to determine the improvement priorities based on the highest RPN values."

Improve

At this stage, improvement suggestions are made to reduce defects related to the incorrect marking of the ID on the tubular heater products. The proposed improvements are focused on addressing the root causes identified from factors analyzed using the fishbone diagram. At this stage, the FMEA (Failure Mode and Effect Analysis) method is used to determine the values for severity, occurrence, and detection, which results in a Risk Priority Number (RPN). By sorting the RPN values from highest to lowest, a priority order for improvements is established. In addition to FMEA, to facilitate the process of implementing corrective actions, it is necessary to plan the actions following the 5W+1H principles (Why, What, Where, When, Who & How). By identifying each failure mode's cause, clarifying what needs to be improved, why it should be fixed, where the fix should be made, who will carry out the fix, and how it will be corrected, the actions will be more targeted and effective

Table 2. Failure Mode and Effect Analysis of Defect Tubular Heater

factors of cause	Main Cause	Root Cause	Control Tool	*Severity Rating* (S)	*Occurrene Rating* (O)	*Detection Rating* (D)	*Risk Priority Number*	*Ranking RPN*
Work	Use of inappropriate bending molds	The molds are not complete	Inspection of production equipment completeness	6	7	7	294	1

Method	The annealing process is not suitable	Failure to follow the SOP	Existence of SOP	5	5	4	100	4
Machine	The machine performance has declined	Lack of regular machine maintenance	Report of machine damage	5	6	7	210	3
Man	Level of operator fatigue	The variety of products	Weekly work check sheet	6	7	6	252	2
Material	Not according to specifications	Material replacement	SPK checking	5	6	2	60	5

It is concluded that the root cause of the incomplete availability of molds is the main priority for improvement, with an RPN value of 294. This type of failure is categorized as moderate. After conducting an analysis using FMEA, the highest RPN value was obtained from the root cause of the defect in the tubular heater, which was the incorrect use of the bending mold. The result of this calculation will be used to implement improvements using the 5W + 1H method.

Table 9. 5W + 1H Analysis of The Root Cause of Defects in The Tubular Heater

No	Potential Cause	What	Why	Where	When		Who	How
1	The unavailability of complete bending molds	Adding and completing the bending mold work tools	Incorrect ID marking is caused by the incomplete bending mold work tools	In the bending area of the tubular heater	Immediately (Proposed at the quarterly meeting, which is in September)		Production Leader	The Production Leader coordinates with the General Manager to propose the addition and creation of bending mold work tools to the factory manager
2	Not following the SOP	Improving the supervision of SOP implementation and posting the SOP at each work station	Reducing the potential for failures caused by operators not following the SOP	In the production area of the tubular heater	Immediately (Proposed at the quarterly meeting, which is in September))		Production Leader	The Production Leader conducts regular and scheduled supervision to hold briefings and coordinate the placement of SOPs at each production process station of the tubular heater.
3	Machine malfunctions during operation	Perform regular maintenance on the marking machine	Reducing the potential for failure in the marking process	In the production area of the tubular heater	Immediately (Proposed at the quarterly meeting, which is in September)		Production Leader and Operator	The Production Leader creates a weekly checklist for the production machine operator's inspection
4	The operator is inattentive" or "The operator is less careful.	Conducting a briefing before starting work and supervising the operator	Reducing the potential for errors during the production process	In the bending area of the tubular heate	Immediately (Proposed at the quarterly meeting, which is in September)		Parts Production Manager and Production Leader	The Production Manager creates a schedule for the Production Leader to conduct regular supervision and daily briefings.
5	The material used is incorrect	Checking the work STK and the actual materials received, ensuring the regular availability of materials, and coordinating with R&D	Reducing the occurrence of errors in the use of tube material	In the production area of the tubular heater and the warehouse.	Immediately (Proposed at the quarterly meeting, which is in September)		Production Leader, Production Manager, and R&D	Create a checklist for material requests and actual materials to be filled out by the production operator, and prepare a report for the Production Manager and R&D to conduct an inspection if there is a material change.

The root cause with the highest RPN value is the incomplete availability of bending molds, which causes the molds used in the bending process to be incorrect in size. As a result, bending with incorrect molds will create products with a defect in shape, causing the tubular heater product to be rough and uneven, leading to the ID marking being unreadable or even erased. The result of this calculation will be used to implement improvements.

Control

1. For the potential cause of the unavailability of bending molds, the improvement is made by proposing and creating bending mold work tools.
2. For the potential cause of not following the SOP, the improvement is made by having the production leader supervise the implementation of the SOP and posting the SOP at each tubular heater production station.
3. For the potential cause of machine malfunctions during operation, the improvement is made by creating a daily checklist for machine operators in the tubular heater production process and a monthly inspection form.
4. For the potential cause of inattentive operators, the improvement is made by creating a regular supervision schedule.
5. For the potential cause of using incorrect materials, the improvement is made by creating a material receipt checklist, an actual goods checklist, and a report on material changes.

CONCLUSION

After conducting an analysis using the DMAIC method and designing improvement proposals based on the 5W+1H principles, several improvement steps have been proposed.

1. A form for requesting bending mold work tools and a plan for creating bending molds have been developed to address the issue of incomplete mold availability.
2. To handle potential machine malfunctions during operation, the creation of a daily machine condition checklist has been proposed as a regular monitoring step, along with a routine maintenance form to maintain the machine's operational condition.
3. To address the potential cause of operator inattention, it has been proposed to create a briefing schedule and regular supervision to be conducted by the PIC of the tubular heater.

REFERENCE

[1]. Central Bureau of Statistics. (2022). 2022 Manufacturing Industry Directory

[2]. C.R & Thakkar. (2019). Application of Six Sigma Dmaic Methodology to Reduce the Defects in a Telecommunication Cabinet Door manufacturing process a case study. Internation al Journal of Quality & Reliability Management Vol. 39(9) 1540-1555. 2019

[3]. Gaspersz, V. (2008). Total Quality Management. In Jakarta: PT. Gramedia Pustaka Utama (V).

[4]. Gupta, V., Jain, R., Meena, M. L., & Dangayach, G. S. (2018). Six-sigma application in tire-manufacturing company: a case study. Journal of Industrial Engineering International, 14(3), 511–520.

[5]. Hairiyah, N., Amalia, R. R., & Luliyanti, E. (2019). Statistical Quality Control Analysis (SQC) In the bread production at Aremania Bakery. Industria: Journal of Agroindustry Technology and Management, 8(1), 41 48.

[6]. Harpensa, A., Harsono, A., & Fitria, L. (2015). Quality Improvement Proposal Using the Six Sigma Method to Reduce the Number of Defects in Terrazzo Tile Products at PT. Ubin Alpen. Online Journal of the National Institute of Technology.

[7]. Heizer, Jay and Barry Render. 2006. Operations Management. Jakarta : Salemba Empat.

[8]. Mohammad Kholil & Prasetyo. (2017). Quality Review of Aerosol Can Ø 65 X 123 Using the Six Sigma Method Approach on Line ABM 3, Assembly Department. SINERGI Vol. 21, No. 1, Februari 2017: 53- 58

[9]. Saludin. 2016. Six Sigma Project Work Guide. Jakarta: Mitra Wacana Media.

[10]. Sukwadi R et all. 2021. Reduction in Rejection Rate of Soy Sauce Packaging via Six Sigma. Industrial Engineering Journal, Vol. 22, No. 1, Year 2021.

[11]. Utomo & Rimawan. (2020). Reduction of Ng Flow Out & Ng Ratio on Bracket Comp Jack Part Using the Lean Six Sigma DMAIC Method. Journal Industrial Servicess Vol. 5 No. 2. 2020

[12]. Warinah & Nusranin. (2019). Application Of Six Sigma (Dmaic) Method to Reduce Defect Amount in Assembly Process A Case Study PT. XYZ. Internation al Humanitie's and Applied Science Journal, 2019.