# Application of SPC and FMEA Methods to Reduce the Level of Hollow Product Defects

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## ABSTRACT

*Case study conduct on a manufacturing company that produces hollow and pipe from rolled iron plate. The production data showed that during January up to October 2021 there were still defects products with the percentage greater than 5%. The specified tolerance limit for defects. In order to maintain quality and increase production efficiency, this company strives to reduce the defect rate. This study aims to reduce the level of defect by using Statistical Process Control methods and the Failure Mode and Effects Analysis (FMEA) method to analyze the level of the worst defects by finding the highest damage value Risk Priority Number (RPN). Histogram showed that the biggest defect occurs in welding (7,51%). Analysis using Fishbone diagram found that the welding defect mostly occur due to human factor, machines, methods, materials, and the environment. The result of FMEA method analysis showed machine setting had the highest RPN and became the first priority to solve. It happened because there is no SOP yet that contains definite engine parameters, such as engine speed and voltage. Based on these results, this study suggests companies to prepare SOPs to be a guide for operators at work.*

**Keywords:** *Defect, FMEA, Fishbone Diagram*, Q*uality, Statistical Process Control (SPC),*

## Introduction

In this era of globalization, every company must maintain product quality to compete and survive. Efficiency and quality are the keys for companies to have global competitiveness (Manova and Yu, 2017). PT. Surya Baja Pipa Indonesia (SBPI) is a manufacturing company that produces hollow and pipe from rolled iron plate. The company has set quality standards for these hollow with a maximum defect tolerance limit of 5%. However, production data from January to October 2021 shows that there is a defect that exceeds the said tolerance limit. This is not in line with the company's goal to maintain the quality of its products in order to satisfy consumer and at the same time increase production efficiency.

The purpose of this study is to identify the most dominant defect that occurs in hollow product and to find out the cause of the defect and to provide recommendation for improvements to reduce the number of defects in hollow product. This study uses the Statistical Process Control method followed by Failure Mode and Effect Analysis (FMEA) to determine the priority of the main causes of defects based on the RPN (Risk Priority Number).

## Methodology

In this study, data collection was carried out through field research with direct interviews and direct observations as well as documentation studies of PT. SPBI. The production data used in this study is the production data of hollow products for the period of August – October 2021, which shows that defect products are still greater than 5%, the maximum tolerance limit that set by the company. The production data was processed using the SPC method and followed by the FMEA method. Furthermore, from the analysis results will be obtained recommendations for improvement in order to reduce the percentage of defects in PT. SBPI.

## Result and Discussion

### A. Analysis Using SPC (Statistical Process Control)

SPC is an application of statistical methods used to monitor standards, make measurements and take corrective actions during the production process of products or services (Heizer dan Render, 2006). With SPC, it is expected that the production process will run smoothly as the plan to meet product specification. Variations that arise during the production process can be immediately detected and corrected so as to reduce product defects or waste and even avoid defective products being sent to customers. This is the advantage using SPG rather than other inspection methods that detect and repair after a problem occurs (Mason & Antony, 2000).

SPC analysis begins with preparing a check sheet, follows by histogram diagram, control chart (p-chart), Pareto diagram and fishbone diagram as follows:

1. Check Sheet contains information on observation times, types of defects and production quantities making it easier to inspect (Fachriyah, 2021). The

production data of hollow products for the period August – October 2021 is shown in Table 1.

Table 1. Production Data of Hollow Product for the Period of August – October 2021

| No | Date | Total Production | Type of Defect | | | Total Product Defect (Kg) | Defect Product (%) |
|---|---|---|---|---|---|---|---|
| | | | Welding | Form | Surface | | |
| 1 | 02/08/2021 | 31150 | 2210 | 200 | 80 | 2490 | 7,99% |
| 2 | 03/08/2021 | 30040 | 2170 | 310 | 90 | 2570 | 8,56% |
| 3 | 04/08/2021 | 33540 | 2220 | 460 | 50 | 2730 | 8,14% |
| 4 | 05/08/2021 | 28450 | 2040 | 190 | 110 | 2340 | 8,22% |
| 5 | 06/08/2021 | 27150 | 2090 | 200 | 70 | 2360 | 8,69% |
| 6 | 06/09/2021 | 29510 | 2280 | 80 | | 2360 | 8,00% |
| 7 | 07/09/2021 | 30610 | 2380 | 300 | 60 | 2740 | 8,95% |
| 8 | 08/09/2021 | 31720 | 2320 | 130 | 130 | 2580 | 8,13% |
| 9 | 09/09/2021 | 28550 | 2200 | 290 | 100 | 2590 | 9,07% |
| 10 | 10/09/2021 | 26370 | 2090 | 10 | | 2100 | 7,96% |
| 11 | 05/10/2021 | 34220 | 2520 | 450 | | 2970 | 8,68% |
| 12 | 06/10/2021 | 33450 | 2530 | 60 | 100 | 2690 | 8,04% |
| 13 | 07/10/2021 | 36010 | 2710 | 440 | 120 | 3270 | 9,08% |
| 14 | 08/10/2021 | 39640 | 3160 | 410 | 90 | 3660 | 9,23% |
| 15 | 09/10/2021 | 38280 | 3050 | 210 | | 3260 | 8,52% |
| Total | | **478690** | **35970** | **3740** | **1000** | **40710** | |
| Percentage of Defect Product | | | 7,51% | 0,78% | 0,21% | 8,50% | |

2. Histogram Diagram

Histogram is a bar chart that depicts the characteristics and variable information of a product or process, also helps users show the circulation of data and how much variation in a process (Neyestani, 2017). Figure 1 shows the histogram of the Hollow defect product based on data from Table 1.

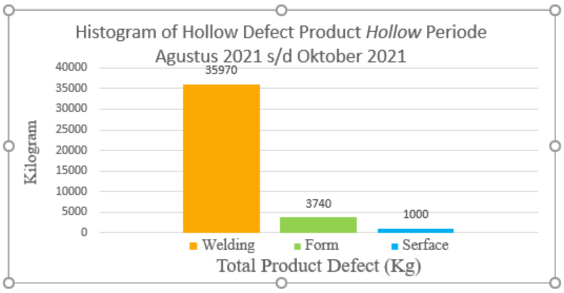


Figure 1. Number of Hollow Product Defects From of August - October 2021

Based on the histogram on Figure 1, it can be seen that the largest type of defect occurs in welding as much as 35,970 Kg, the number of shape defects as much as 3.740 Kg, and the number of surface defects as much as 1,000 Kg.

3. Control Chart (p-chart)

Calculating the percentage of defects, central line, Lower Control Limit (LCL) and Upper Control Limit (UCL) are presented in the graph (see Figure 2).

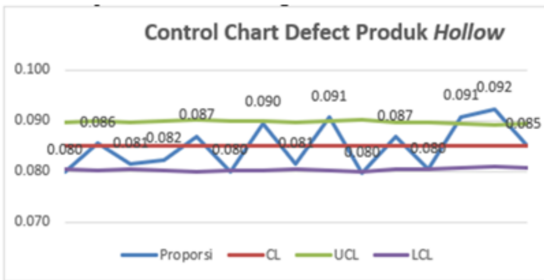


Figure 2. Control chart of Defect Hollow Product

Figure 2 showed there are 3 samples that are outside the control limits, namely sample no. 9 (value 0.091), 13 (value 0.091) and 14 (value 0.092).

4. Pareto Diagram

Processing data from Table 4 found that there were 3 types of defects named welding with the highest percentage, followed by shape defects and surface defects, as shown in Figure 3.

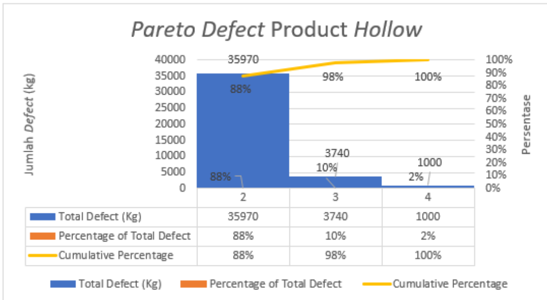


Figure 3. Pareto Diagram of Defect Product Hollow

5. Fishbone Diagram

Welding defects have the largest percentage as shown in Figure 3. An analysis is carried out using a fishbone diagram to determine the causes of defects which are grouped into 5 factors, namely human, material, machine, method and environment as shown in Figure 4.

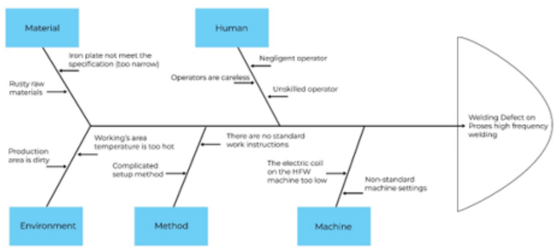


Figure 4. Fishbone Diagram Welding Defect

**B. Analysis Using FMEA Method**

The FMEA method is a powerful method used to detect exactly where problems can occur and prioritize treatment in order of severity (Dale et al., 2003). FMEA has been widely used in various industries such as manufacturing, electronics, chemical, medicine, textile and others as an effective control tool to analyze and improve the quality and reliability of the system (Wu, et al., 2021). FMEA begins by identifying the source causing the defect, then calculating the Risk Priority Number (RPN). RPN is a measure used when assessing risk to help identify critical failure modes related to a design or process. The RPN value is obtained from multiplication of severity, occurrence and detection values. Severity is the extremity or effect that a failure mode has on the entire machine. The Severity rating value is between 1 to 10, as shown in Table 2.

Table 2. Severity Rank

| Code | Classification | Example |
|---|---|---|
| 10 | Hazardous Without Warning | Very High Ranking – Affecting safe operation. |
| 9 | Hazardous With Warning | Regulatory non compliance |
| 8 | Very High | Product becomes inoperable, with loss of function – Customer Very Much Dissatisfied |
| 7 | High | Product remain operable but loss of performance – Customer Dissatisfied |
| 6 | Moderate | Product remain operable but loss of comfort/convenience - Customer Discomfort |
| 5 | Low | Product remain operable but loss of comfort/convenience - Customer Slightly Dissatisfied |
| 4 | Very Low | Nonconformance by certain items – Noticed by most customers |
| 3 | Minor | Nonconformance by certain items – Noticed by average customers |
| 2 | Very Minor | Nonconformance by certain items – Noticed by selective customers |
| 1 | None | No Effect |

Source: Stamatis, 1995

Occurrence is the frequency of damage or failure occurs. It is related to the estimation of the cumulative number of failures that arise due to a certain cause on the machine, identify the potential cause of failure from the failure mode (error) and provide level of occurrence. The occurrence value ranges from 1-10, as shown in Table 3.

Table 3. Occurrence Rank

| Code | Classification | Example |
|---|---|---|
| 10 and 9 | Very High | Inevitable Failure |
| 8 and 7 | High | Repeated Failures |
| 6 and 5 | Moderate | Occasional Failures |
| 4, 3 and 2 | Low | Few Failures |
| 1 | Remote | Failure Unlikely |

Source: Stamatis, 1995

Detection rank is given to the control system used today to show the ability to detect the cause or mode of failure. The detection rating value ranges from 1 to 10, as shown in Table 4.

Table 4. Detection Rank

| Detection | Rank | Criteria |
|---|---|---|
| Extremely Likely | 1 | Can be corrected prior to prototype/ Controls will almost certainly detect |
| Very High Likelihood | 2 | Can be corrected prior to design release/Very High probability of detection |
| High Likelihood | 3 | Likely to be corrected/High probability of detection |
| Moderately High Likelihood | 4 | Design controls are moderately effective |
| Medium Likelihood | 5 | Design controls have an even chance of working |
| Moderately Low Likelihood | 6 | Design controls may miss the problem |
| Low Likelihood | 7 | Design controls are likely to miss the problem |
| Very Low Likelihood | 8 | Design controls have a poor chance of detection |
| Very Low Likelihood | 9 | Unproven, unreliable design/poor chance for detection |
| Extremely Unlikely | 10 | No design technique available/Controls will not detect |

Source: Stamatis, 1995

Based on the information from fishbone diagram, we determine the degree of severity, occurrence and detection to obtain the RPN, as presented in Table 5. The RPN value from the highest rank to the lowest as follows:

a. First Rank with RPN value of 360 indicates that the engine settings are the most important factor. Machine settings are relatively complicated and do not have standard parameters yet, especially in determining engine speed and power voltage. It happens because there is no SOP for setting the machine, so the operator works based on his experience. This non-standard setting causes high product defects.
b. Second Rank with RPN value of 294 relate to machine and tools. Production tools have an important role. Using unstandardized production tool causes the unstable movement of welding machine nozzle, where the distance between the welding arc and the workpiece to collide with each other, as a result, the metal liquefaction system becomes shaky and the welding results are coarse.
c. Third Rank with RPN value of 150 relate to quality of raw materials. Materials that are too rigid (hard) complicate the welding process so that the welds often re-open and produce defective products. However, quality of raw material affects the quality of end product.

Table 5. FMEA of Product Defects in the Welding Process

| Expected Product Characteristics | Mode of Failure | Case of Failure | Effect of Failure | Degree of Severity (1-10) | Freq. of Occurrence (1-10) | Chance of Detection (1-10) | Risk Priority Number (1-1000) | Rank |
|---|---|---|---|---|---|---|---|---|
| Product with free welding defects in the HFW process | Unskilled operator (doesn't understand SOP) | Unavailable the scheduled training | Operator doesn't understand how to set up the machine | 4 | 3 | 3 | 36 | 4 |
| | Unstandardized machine setting | Unavailable machine setting SOP | A lot of Product defect | 9 | 8 | 5 | 360 | 1 |
| | Varied quality of raw materials | Rusty and stiff raw material | Imperfect welding of raw materials | 5 | 5 | 6 | 150 | 3 |
| | Unstandardized production tool | Unavailable schedule of welding machine (HFW) maintenance | welding results are coarse | 6 | 7 | 7 | 294 | 2 |
| | Room temperature is high (above standard) | Insufficient air ventilation | Affecting concentrate and performance quality of the operators | 3 | 3 | 3 | 27 | 5 |

d. Fourth rank with RPN of value 46 indicates unskilled operator. Unskilled operator who doesn't master SOP will not be able to operate the machine optimally and affected product.

e. Fifth rank as the lowest rank with RPN value of 27 relate to environment. A comfort environment will improve operator performance. Insufficient air ventilation makes the workspace hot, thus affecting the concentration and performance of workers.

Based on the results of the analysis using the FMEA method, we come with the following recommendations to prevent defects in the future, which are:

1. Method factor: Type of machine setting error with RPN value of 360. There is no available SOP of machine settings and standard machine parameters become the main cause of failure.
   a. Current preventive controls: The setup process relies solely on operator experience.
   b. Action recommendations: compiling Standard Operating Procedures (SOP) in the production process and machine standard parameters for machine settings.
2. Machine/tools factor: Type of production tools error with an RPN value of 294.
   a. Current prevention control: not available yet
   b. Recommended action: Prepare maintenance schedule, especially for welding machines to make sure the machine will work optimally
3. Raw material factor: Raw material error type with RPN value of 150
   a. Current prevention control: there is no raw material inspection procedure
   b. Recommended action: Prepare raw material specification and SOP for receiving raw materials
4. Human factor: Type of operator skill error with RPN value of 36
   a. Current prevention control: Operator briefing when an error occurs on the spot
   b. Recommended action: provide scheduled training to improve operator and technician skills as well as creating a sense of responsibility.
5. Environmental Factors: Hot working space with RPN value of 27.
   a. Current prevention control: Provide fans in production room
   b. Recommended action: make a large ventilator at the top of the room (wind driven fan), especially in the production area

The results of this study support the previous research conducted by Amperajaya, 2014 which used the FMEA method to obtain 3 factors causing defects that had the largest RPN while at the same time providing recommendations for the Socket Bolt M 6x16 mm product at PT. XYZ; research by Mascia, et al., 2020 that uses the FMEA method to identify errors and their impact on results and then determine corrective actions that cover most aspects of laboratory practice, in particular equipment management and staff training; Kaban's research, 2016 which uses SPC to detect the cause of production rejects in cooking oil packaging at PT. Incasi Raya; researched by Bahari, et al., 2018 at PT. Astra Daihatsu Motor using SPC shows the results that the Main body production still needs improvement to reduce the number of defects.

## Conclusion

The results of the analysis using the SPC tool show that the most defects occur in welding caused by human factors/workers, machines, methods, materials and the environment. By using the FMEA method, the highest RPN value is obtained in the method factor followed by the machine factor and raw materials. The use of these two methods helps companies to detect the root causes of defects and at the same time obtain recommended actions to prevent defects in the future.

Based upon the results of the analysis using the FMEA method, it can be seen that the main factor causing damage to the welding process is the machine setting that does not have a standard operating procedure. Therefore, the preparation of SOPs for machine management is a top priority to reduce the level of defects in the Hollow production process.

Further research can combine the SPC method with other quality control methods, such as Six Sigma and others

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