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IMPLEMENTATION OF QUALITY IMPROVEMENTS TO MINIMIZE CRITICAL TO QUALITY VARIATIONS IN POLYURETHANE LIQUID INJECTION PROCESSES

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ABSTRACT
PT Topjaya Antariksa Electronics is a manufacturing company that produces various refrigerators, home freezers, and showcase refrigerators. Refrigerators are produced in the form of single doors and twin doors. This company was founded in 1988 and distributed by Toshiba Sarana Utama throughout Indonesia. This research is intended to reduce the process failure rate so that the potential for defects produced in the polyurethane shop is reduced by finding repair solutions. This study aims to plan improvement efforts to reduce process failures in the polyurethane shop and then evaluate the results of implementing the proposal. The FMEA (Failure Mode and Effect Analysis) method is used. This method performs several stages, such as determining the potential failure mode in each process, identifying the cause of failure, and then making a priority order. Process failure in this polyurethane shop is the most significant process failure compared to other shops. This failure causes the defects in the process at the polyurethane shop to be higher than in other shops. In 2019, 2020, and 2021, the number of refrigerator cabinets in the flawed polyurethane injection process amounted to 7,666 units, 8,256 units, and 8,014 units. The percentage of defects compared to the amount of production found in the polyurethane injection process each year was 18.46%, 17.82%, and 18.11%.
Keywords: *Failure Mode and Effect Analysis, Polyurethane Shop, Process Failure, Risk Priority Number.*

1. Introduction

The diversity of these products forces manufacturers to continue to improve the quality of the products produced by the wishes of consumers. Defective products are the primary source of waste (Puspitasari, et al., 2017; Ramadhani, et al., 2014). According to (Hidayat and Rochmoeljati, 2020), Quality improvement in large-scale industry or SME scale has been researched and developed to analyze product quality improvements using the FTA (Fault Tree Analysis) and FMEA (Failure Mode and Effect Analysis) methods. The level of product or service quality as expected, carried out using planning, appropriate methods, routine supervision, and corrective action if an unsuitable condition is found so that quality control can be carried out correctly and according to existing standards(Awal & Hasegawa, 2015; Djunaidi & Ryantaffy, 2018).

Polyurethane shop has failure problems during the polyurethane injection process with the highest failure rate compared to other processes. The specifications of the polyurethane liquid weight at the time of polyurethane injection set by the company are 2,320 ± 70 grams. If the injection exceeds or is less than the specified specifications, it can cause failure(Fathoni & Hakim, 2019). This failure is in the form of advantages and disadvantages of polyurethane injection in the refrigerator cabinet, resulting in leakage of the inner Liner, dents on the inner Liner, and space between the inner Liner and the surrounding plate. This problematic refrigerator cabinet required disassembly by removing the inner Liner and injecting polyurethane foam. Then after disassembly, this refrigerator cabinet was injected again with polyurethane to get better results. Rework is what causes the company's costs for repairs to be high. For this reason, the failure of the process at this polyurethane shop needs to pay more attention to identifying the cause of the failure and find a solution to repair it so that the number of defects can be reduced(Balaraju, et al., 2019; Faturachman, et al., 2014; Mostafa & Fahmy, 2020).

2. Literature Review

According to Ahmad and Yusanto (2020), defects are products that do not meet the quality standards set and cannot be continued to the following process stage. This product with reconditioning costs for the repair process. Economically the product can be improved by becoming a better-finished product. The results of previous research showed that five types of defects were found: hollow defects with a probability value of 6.5%, charred defects with a probability of 5.9%, and solid defects with a probability of 6.9%(Gunawan & Tannady, 2016).

This study (Joko, 2018) analyzed the causes of defective t-shoes using the FTA and FMEA methods at PT. Industry Panarub. The results of the discussion of this study show the sewing process with a value of 576 and assembling a score of 512. Those who get the highest RPN value have a significant defect rate. Failure Mode and Effect Analysis (FMEA) is one method of evaluating system risks. FMEA can evaluate and analyze components in the system so that it can minimize the risk or effect of a failure rate as a supporting method for evaluating the performance of a system (Imanuell & Lutfi, 2019). The role of the FMEA method itself can be used to determine the risk of accidents in the system (Sukwadi et al., 2017), the risk of component production failure (Hasbullah et al., 2017), supply chain system risks (Liu et al., 2018; Latif, et al., 2018).

Research on maintenance analysis by detecting the risk of failure in machines or tools can be used with the FMEA method. As a result, three critical components must be prioritized in maintenance: the stick cylinder, fuel filter, and oil pan (Darmawan et al., 2017). Another study discusses the analysis of machine maintenance in an agro-industry using the FMEA method. The result is three classification categories for performing treatment (Soewardi & Wulandari, 2019). Risk assessment with the FMEA method can use a qualitative value scale by identifying several predetermined criteria. This assessment can optimize the maintenance plan (Arabian-Hoseynabadi et al., 2010) on the ship's main engine. This study used this method to identify the parameters that exist in FMEA, among others (Priharanto et al., 2017; Surya et al., 2017). Failure Mode and Effect Analysis (FMEA) is one method of evaluating system risks. FMEA can evaluate and analyze components in the system so that it can minimize the risk or effect of a failure rate as a supporting method for evaluating the performance of a system (Imanuell & Lutfi, 2019; Islam, et al., 2019; Kusdiantoro, et al., 2019).

3. Research Methods

The methodology is a stage in research to determine the steps and framework of thinking in formulating, analyzing, and solving problems. With the research methodology, it is hoped that the flow of problem-solving thinking becomes more focused and systematic so that it will be easier to analyze and draw conclusions. The systematic flow of the research methodology used can be seen in Figure 1.

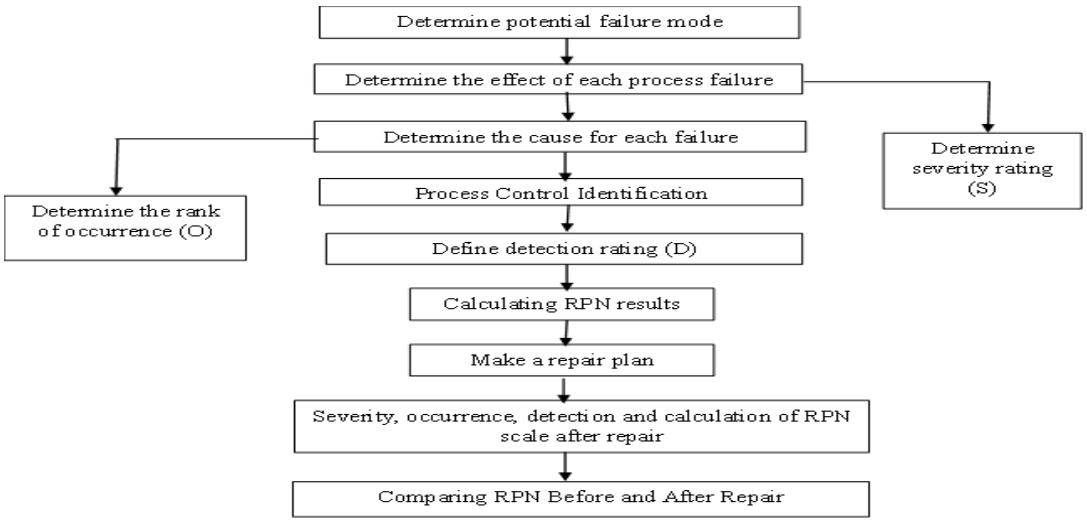

Fig. 1. Framework of Thinking Methodology

In this research method, there are two types of data, namely:
Primary data is data obtained from a source directly observed in this case, the process of injection of polyurethane liquid at a polyurethane shop. The data obtained include the following.

a. Defect data on polyurethane, press, CRF, and vacuum forming shops in August-September 2021.
b. Sampling data on polyurethane weight for August-September 2021 at a polyurethane shop for a refrigerator type N-188-JZ.

The problem analysis uses FMEA (Failure Mode and Effect Analysis), which consists of several stages.

a. Determine the potential failure mode for each process.
   Identify processes that have the potential to fail to meet process or design requirements.
b. Identification of failure effects
   Identify the effects of failure on both internal and external customers. Identify the effects of each process and their impact on the following process.
c. Determine the severity value
   Determine the severity value based on the consequences/effects arising from the failure.
   Identify the causes of failure
d. Identify potential causes for each process failure using a cause-and-effect diagram.
e. Determine the occurrence value
   Determine the value of how often the cause of failure occurs.
f. Identify process controls
   Identify control methods that can prevent potential failure/cause or detect failure/cause.
g. Determining the detection value
   Determines the value of the system's ability to detect a failure.
h. Calculate the value of the Risk Priority Number (RPN).
   RPN is a number that states the priority scale for quality risk, which is used as a guide in carrying out improvement plans.
i. Making a Repair Plan
   Improvements can be made by prioritizing the process with the highest RPN value.

4. Results and Discussions

Identify Critical to Quality

The polyurethane shop is a workstation with the most significant number of defects compared to other stations. Other workstations include Press shop, CRF shop, and Vacuum Forming. Defect data obtained from the four processes are as follows*:*

Table 1 - Number of Defects Produced by Each Process

Process Type	Production Period 2020
	August-September (Unit)
Press Shop	120
CRF Shop	130
Vacuum Forming Shop	650
Polyurethanen Shop	1.491
Total Product Defect	2.391
Total Production	36.673

A. Identify Potential Failure Modes with FMEA

A potential failure mode is a state in which a process could fail to meet process or design requirements(Nazaruddin & Septiani, 2021). The potential failure mode can cause the failure mode in the following process' or the 'effect of the potential failure in the previous process. The following are the potential failure modes of the polyurethane injection process in Table 2.

Table 2 - Potential Failure Mode of Polyurethane Filling

Product Characteristics	Potential Failure
Polyurethane Liquid Filling Volume Suitability	Advantages of Polyurethane Liquid Filling Disadvantages of Polyurethane Liquid Filling

B. Determining Consequences of Process Failure

Table 3. effects of each process for each component. The consequences of potential failures that arise in the polyurethane injection process.

Table 3 - Consequences of Potential Failure

No	Types of Potential Failure	Consequences of Potential Failure
1	Advantages of Polyurethane Liquid Filling	Polyurethane Leakage ▪ Torn inner Liner ▪ The cabinet must be dismantled ▪ Inner Liner cannot be reused Dented Inner Liner ▪ Inner Liner is dented ▪ The cabinet must be disassembled ▪ Inner Liner cannot be reused
2	Disadvantages of Polyurethane Liquid Filling	Polyurethane Empty ▪ Cabinet must be dismantled ▪ Innerliner cannot be reused ▪ Between the cabinet and the innerliner there is quite a lot of confined air ▪ Resulting in a fairly large void area in the cabinet ▪ Feels soft in a fairly large area Innerliner Not Sticking ▪ Cabinet must be dismantled ▪ Innerliner cannot be reused ▪ Between the cabinet and the innerliner there is a little trapped air ▪ The void area is small while the surrounding area is filled with polyurethane well ▪ Feels soft when pressed

C. Determining the Severity Value

Severity is a serious statement about the potential effect of this type of failure on the next component, sub system, system or customer if this failure occurs. The severity values obtained include, among others, in Table 4.

Tabel 4 - Severity Value

No	Types of Potential Failure	Effect of Potential Failure	*Severity*
1		Polyurethane Leakage ▪ Torn inner Liner ▪ The cabinet must be dismantled ▪ Inner Liner cannot be reused	7
	Advantages of Polyurethane Liquid Filling	Dented Inner liner ▪ The inner liner inside the cabinet is dented so that it looks like a lump ▪ The cabinet must be disassembled ▪ The inner liner cannot be reused	7
2		Polyurethane Empty ▪ Innerliner cannot be reused ▪ Between the cabinet and the innerliner there is quite a lot of confined air ▪ Resulting in a fairly large void area in the cabinet ▪ Feels soft in a fairly large area	7
	Disadvantages of Polyurethane Liquid Filling	*Innerliner Not Sticking* ▪ Cabinet must be dismantled ▪ Innerliner cannot be reused ▪ Between the cabinet and the innerliner there is a little trapped air ▪ The void area is small while the surrounding area is filled with polyurethane well ▪ Feels soft when pressed	7

D. Determining the Occurance Value

Occurance is how often the cause of failure occurs. Occurrence value can be determined based on management's experience so far in dealing with process failure problems in the polyurethane injection process. The occurrence values obtained include, among others, in Table 5.

Table 5 - Determination of the Occurance Rating Scale

No	Potential Failure	Causes of Process Failure	Occurance
1	Polyurethane Leakage	Inner Liner quality is lacking	4
		Operator is tired	7
		Lack of operator skills	5
		Manual injection	7
		Injection nozzle stuck	5
		Hot room temperature	9
2	Innerliner Dented	Operator is tired	7
		Injeksi manual	7
		Less supervision	7
		Innercore doesn't match inner liner	2

		Operator is tired	7
		Lack of operator skills	5
3	Polyurethane Empty	Less supervision	7
		Engine cylinder head stuck	5
		Polyurethane liquid is not homogeneous	4
		Air trapped in cabinet	3
		Polyurethane liquid is not homogeneous	4
4	Innerliner not Sticking	Lack of operator skills	5
		Injection nozzle stuck	5
		The material filter is not working properly	5

E. Determining the Detection Value

Detection is a number from 1 to 10, where 1 indicates a detection system with high capability or almost certain that a failure mode can be detected. While 10 indicates a detection system with low capability, where the detection system is not effective or cannot detect it at all. The detection values obtained include the following in Table 6.

Table 6 - Determination of Detection Value

No	Potential Failure	Current control	*Detection*
		Sampling with two samples	4
		There isn't any yet	9
1	*Polyurethane Leakage*	Training once a year	3
		Work instruction	3
		Maintenance once a month	8
		There isn't any yet	2
		There isn't any yet	9
2	*Innerliner Dented*	Work instruction	3
		Supervision	2
		Work instruction	6
		Work instruction	9
		Training once a year	3
3	*Polyurethane Empty*	Supervision	2
		Maintenance once a month	7
		Work instruction	3
		Manual Check	5
		Work instruction	3
4	*Innerliner not Sticking*	Training	3
		Maintenance once a month	8
		Maintenance once a month	8

F. Calculating the value of the Risk Priority Number (RPN)

After knowing the severity, occurrence, and detection values for each potential failure mode, then calculating the RPN value. RPN is a number that states the priority scale for quality risk which is used to guide the improvement plan. The RPN value is seen in Table 7.

Table 7 - Determination of RPN Value

Process	Potential Failure	S	O	D	RPN
Polyurethane Liquid Injection Process	*Polyurethane Leakage*	7	4	4	112
			7	9	441
			5	3	105

			7	3	147
			5	8	280
			9	2	126
			7	9	441
Innerliner Dented	7		7	3	147
			7	2	98
			2	6	84
			7	9	441
			5	3	105
Polyurethane Empty			7	2	98
			5	7	245
			4	3	84
			3	5	105
			4	4	112
Innerliner not Sticking		7	5	3	105
			5	8	280
			5	8	280

G. Improvement

To reduce the number of process failures in the polyurethane filling process at the polyurethane shop, an improvement plan is needed. In making the improvement plan the method used is 5W+1H as a way to find out the solution to the problem. These improvements are listed in Table 8. as follows.

Table 8 - Repair Control Table

Process	Potential Failure	Factor	Why	Where	Current control	How	When	Who
Polyurethane Liquid Filling Process	*Polyurethane Leakage*	Material	Inner Liner quality is lacking	IQC *(Incoming Quality Control)*	Inspection of two samples at random	Inspection of ten samples at random	When materials come	IQC Staff
		Man	Operator is tired	*Polyurethane Shop*	There isn't any yet	Two times the change of operator who performs injection every one work shift	Replacement is made after half shift time	Polyurethane Shop Supervisor
		Man	*Lack of operator skills*	*Polyurethane Shop*	Training once a year	-	once a year	Production Department

5. Conclusion

Based on the calculation of the capability value of the polyurethane liquid filling process before the repair, the Cp value is 0.41 and Cpk is 0.39. After the implementation of the improvements obtained a Cp value of 0.65 and a Cpk of 0.62. After the implementation of the improvements there was an increase in the value of the process capability. Meanwhile, the accumulated value of the Risk Priority Number before the repair was highest on polyurethane leakage with an RPN value of 1,085. Then followed by polyurethane empty of 973, dented innerliner of 896, and not sticking of 882. After implementation of the improvements, the largest value was obtained, namely innerliner not sticking with an accumulated RPN value of 490. Then followed by polyurethane empty, polyurethane leakage, and dented innerliner. Each has accumulated RPN values of 399, 385, and 322. This accumulated value decreased after the implementation of the improvements.

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