Assessing Cause of Defect Using FMEA (Failure Mode and Effect Analysis)

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ABSTRACT

A company should implement good quality management to maintain consumer confidence in producing quality products. FMEA serves to identify product failures in a process and the causes of defects or losses that occur during the production process of a product, component, or system. The research aims to analyze quality control and identify production defects that cause a decrease in quality. The samples studied were rejected goods in production activities. Forty damaged parts were used as the samples in this study. This study used both qualitative and quantitative analysis. Quantitative analysis was conducted to determine the type of rejection and then to rank the risk, while qualitative analysis was performed with Ishikawa diagram to evaluate risk priorities. This research not only helps identify and assess the root cause of rejected goods but also affects the following year's planning by proposing measures to reduce risk. Check sheets and histograms are used to present further research. The analysis results show two classifications of defects in production: size error and painting error, with the most dominant defect, size error, and equal to 73.17%. Based on the analysis of the causes of defects, several factors were found that caused product defects; man, material, method, machine. The man factor has the highest value in contributing to defect, with an RPN score of 192.

INTRODUCTION

Quality control is crucial to maintaining a company's reputation in the eyes of consumers and is critical to business success, growth, and competitiveness. The principles of quality assurance apply to manufactured goods and services. As the industrial era is increasing, the diversity of these products forces manufacturers to continue improving the quality of the products that follow the customer's needs. Defective products are a significant source of waste. Some companies face severe problems due to defective products that lead to consumer claims. The company must compensate the consumer if a defective product passes to the consumer and causes a loss. This situation made the company lose potential customers therefore companies need to create good quality in the products they produce and maintain consistency to remain in line with market demands by implementing a quality control system for the process activities undertaken (Ratnadi & Suprianto, 2016).

Quality is a fundamental factor in deciding consumers' products or services. This election is determined without distinguishing the status of consumers, whether individuals, industrial groups, or others. Production should be deployed according each quality characteristic (Dai et al., 2011). Hence, quality is critical for business success, growth, and improvement of the company's competitive position. Quality is defined as meeting customer requirements specifications without the slightest defect (Judi, et al., 2011).

PT Pura Engineering is an industrial company engaged in manufacturing, with its primary product being agricultural machinery. Based on the actual conditions, quality control in this company runs in the preparation, fabrication, assembly, and machining processes. With such a strict quality control process, product defects are still found. One of the production errors occurred due to nesting results that did not match the designed drawings. Defects in the process affect subsequent operations and can cause more defects by means will act in the fabrication and assembly process, which makes an incoherent machining process and lead to a defective product. When a company produces a defective product, the company will discard the product and turn it into waste or rework the product. Both options will equally contribute to production losses. Based on this background, a failure rate of resulting product is analyzed by analyzing defects that occur in such a process.

The FMEA method was first introduced within the aerospace industry and then widely utilized in many industries (H. C. Liu et al., 2019). It is one of the industry's most recognized and widely used proactive risk assessment methods (Shebl et al., 2012). Failure Mode is the failure of a product or process according to its function or cause of loss, while Effect Analysis analyzes the possible consequences of each failure (McDermott et al., 2013). FMEA helps identify, and asses the root cause of reject goods and affect the next year's planning by proposing measures to reduce risk. Applying the FMEA method brings increased value to the process, resulting in a clear assessment of the risks in the organization (Kardos et al., 2021). Therefore, FMEA is a powerful analysis method (L. Wang et al., 2021)

RESEARCH METHOD

The aim of this study is to analyze quality control and identify production defects that cause a decrease in quality with FMEA methods. This study uses the FMEA method by collecting primary data through interviews and secondary data, historical data on production reject goods. All the data that has been collected will then be calculated and judged whether it is within the control range. The methodology of the article is based on the essence of the process FMEA. Among the basic steps of FMEA, it can be achieved with the following steps (Kardos et al., 2021):

1. Identify the subject of the study and define the scope, identify functions, requirements, and specifications.
2. Identify possible ways of problems by defining the type of product defect
    a. Identify the type of product defect based on its proportion.
    b. Make sure that the data is in its margin by using a P-chart
    P- chart (damage proportion control chart) is a tool that can be used for statistical process control. Control chart p was chosen because quality control is an attribute. Monthly records are sampled for non-permanent observations and damaged (defective) products. The P control map shows data changes from time to time, including the maximum and minimum limits, which are the boundaries of the control area. Control charts are used to help detect deviations by setting control limits (Khomah & Siti Rahayu, 2015). This step were carried out by calculating the Central Line, Upper Control Limit (UCL), and Lower Control Limit (LCL). Suppose that the fraction of nonconforming items is $\bar{p}$ and a indicates items that get inspected, with type 3-sigma control limits the formulas for this calculation were as follows (H. Wang, 2009)

$$CL = \frac{\sum Total\ Defect}{\sum amount\ of\ goods} \quad (1)$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{a}} \quad (2)$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{a}} \quad (3)$$

    c. Create and analyze Pareto Charts and Scatter Diagrams
    A Pareto diagram is a diagram that is used to determine a priority category of events so that the most dominant value can be determined by looking at the cumulative value (Grosfeld-Nir et al, 2007). The Pareto principle states with a rule that can be interpreted that 80% of quality problems in a product are caused by 20% of the causes of failure in production, so that the types of failures/defects with a cumulative reach of 80% are selected, with the assumption that the 80% can represent all types of defects that occur. The Pareto chart is an illustration that sorts data classifications from left to right

according to the highest to lowest ranking order. The highest rank indicates the top priority in its completion (Besterfield, 2009).

3. Identify and assess risk by using Ishikawa Diagrams.
The Ishikawa diagram is included as one of the seven basic quality control methods (Perera & Navaratne, 2016). The fishbone or the Ishikawa diagram can help during the initial process of identifying problems. An Ishikawa diagram is one of powerful tools in calculation the management features on the quality yield (Agrawal, 2021).

4. Recommend FMEA measure and result
The Ranking of the Failure will be determined by Risk Priority Number (RPN) calculated by multiplying severity of failures (S), the probability of occurrence (O), and the probability of failure detection (D) (J. Liu et al., 2023).

$$RPN = S \times O \times D \quad (4)$$

RESULTS AND DISCUSSION

Failure Mode and Effect Analysis (FMEA) is a method used to examine the causes of defects or failures during the production process, evaluate risk priorities that cause work accidents, and help take action to avoid problems identified as work accident hazards. The FMEA method combines human knowledge and experience to Identify and evaluate potential failures of a product or process, Assist in the analysis of corrective or preventive actions, and Eliminate or reduce the possibility of failure (J. et al., 2017). While Design FMEA is a type of FMEA that focuses on failure modes caused by design flaws and aims to maximize a design's quality, reliability, cost, and maintainability. FMEA design is carried out on a product or service/service at the design level during the design stage. The goal is to analyze a design system and determine how the failure mode affects the system's operation (Wawolumaja et al, 2013).

The result of the research are explained as follows. The subject of this research is the number of defective products on the production floor. Historical data obtained 40 types of defective products. The defective product data is used to make the P control chart. This P control chart is intended to ensure that the data obtained is still within its control limit. This chart is obtained by calculating the central line, upper control limit and lower control limit. Based on Table 1, it was found that 40 defective products caused production losses. The 40 defective product is all the component that assemble the final agro machine. The 40 defective products were then analyzed by using P-Chart and classified based on the type of cause of the defect. The result of the P-Chart is all the product is within its control range (see figure 1 (a)). The result of classification is two classification errors were found in the production process; size error and painting error. Size error is an error in the size of the product, which causes the product results doesn't suit the design while a painting error is a deviation in the painting process that causes an unmatched product color.

Based on the classification above, the proportion of each defect is obtained. A Bar-Chart explains the depiction of this proportion. The Bar-Chart is used to identify the most common type of damage. From the checksheet data, the most significant type of defect is size error. The number of size error defects is 292 while the number of painting errors is 58. Bar-Chart data is presented in figure 1 (b). In making Ishikawa Diagram it is important to perform data stratification so that patterns and variable relation can be clearly illustrated. Scatterplot have been used widely and one useful technique for illustrating correlation and pattern of low dimensional data (Nguyen et al., 2020). The results of the scatterplot diagram of the two variables in this study, namely total defects and the number of inspected items are shown in Figure 1(d)

Based on the classification and proportion calculation, the most significant type of defect is size error. So, the size error type will be put into calculation. An Ishikawa diagram is used to determine the factors that cause this type of defect. Ishikawa diagram is a reactive risk management method that identifies potential causes of a problem to find the root cause of the situation through a brainstorming session (Wong, 2011). The diagram will identify the causes of size errors in factors/categories of man/personnel, material, mission/environment, method, machine and management (Carvalho et al., 2021). Man/Personnel categories lies in analysis that related with people knowledge. Material categories includes raw material, consumables and information. Methods categories including all performance during making the product. Machine is related to tools to generate data. Mission categories has something to do with environment, and Management categories is something related to leadership. Of all the contributing factors, it is found that there are four main leading categories that contribute to producing defective product. These four categories are man, material, method, and machine. The Ishikawa diagram in this study is shown in figure 2

FMEA analysis is conducted by determining the level of three risk factor such as severity of failures (S), the probability of occurrence (O), and the probability of failure detection (D). The final risk priorities are determined by RPN (Risk Priority Number), which can be obtained by multiplying the (S), (O), and (D).

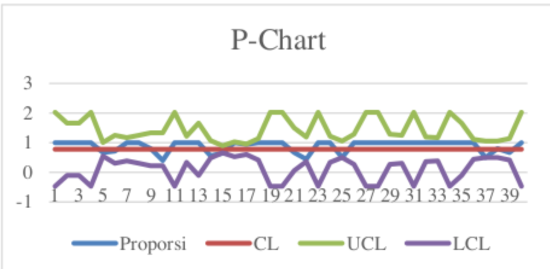

Figure 1 (a) Type of reject

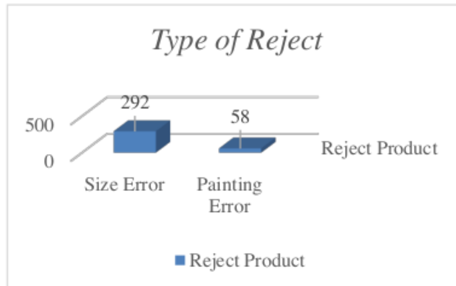

Figure 1 (b) P-Chart

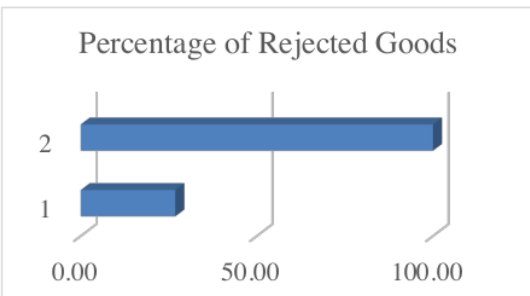

Figure 1 (c) Percentage of rejected goods

Figure 1 (d) Scatterplot

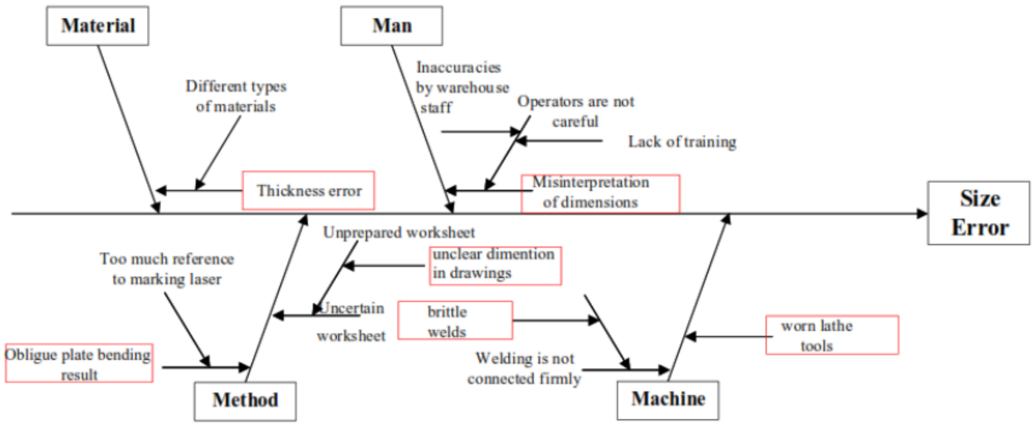

Figure 2 Ishikawa Diagram

Table 1 show the type and sum of product that get defect during production process

Table 1 defective product

No	Date	Products	No	Date	Products
1	18/01/2021	*Dandy roll plain D*	21	21/07/2021	*Flat pulley* 85
2	27/01/2021	*Middle basin*	22	30/07/2021	*Rotary head body* B
3	18/01/2021	*Outlet blower*	23	19/08/2021	*Husker stand* 2 H2PE
4	15/02/2021	*Impeller boiler* ZUG	24	30/08/2021	*Flend*
5	12/03/2021	*Outer slide*	25	10/09/2021	*Frame blower* 1
6	15/03/2021	*Alternator electric box stand*	26	10/09/2021	*Upper stair* 4
7	18/03/2021	*Casing screw* HBI 6	27	22/09/2021	*Stand for tank*
8	25/03/2021	*Front cover* 1 – 717	28	22/09/2021	*Husker Stair-C*
9	06/04/2021	*Impeller BD* 10 *T*	29	27/09/2021	*Left Frame*
10	12/04/2021	*Conch V2 blower fan*	30	27/09/2021	*Valve rotary* 1624
11	15/04/2021	*Reducer outlet SD IT*	31	28/09/2021	*Ducting outlet blower*
12	28/04/2021	*Bearing stand*	32	28/09/2021	*Ducting* 3 DD 10
13	03/05/2021	*Back cover* RU 1624 L *shaft*	33	15/09/2021	*Body profile* 1
14	12/05/2021	*Rolling spindle* B	34	18/09/2021	R *Casing*
15	22/05/2021	*Triangle*	35	06/10/2021	*Reducer Polish*
16	29/05/2021	*Corn extend*	36	06/10/2021	*Ducting* 1 DD 10
17	21/06/2022	*V Pulley* GX 200 NS80	37	07/11/2021	*Arm* 1 VB
18	26/06/2021	*Rod seal ring*	38	10/11/2021	*Rotary cover*
19	05/07/2021	*1P-FP Transmission frame*	39	07/12/2021	*Valve* 2 *Rotary* 1624
20	08/07/2021	*Mounting gear pump pulley*	40	23/12/2021	*Ducting*

Following the quantitative step, an analysis of size error rejection is carried out. The base data for this analysis is taken from the Ishikawa Diagram. The following calculation is determining the level of severity of failures (S), the probability of occurrence (O), and the probability of failure detection (D). This step were performed by 3 production expert in the company with different educational background and full working experience. Rating is given on a scale of 1-10, with 1 being the lowest score given in each item then the average number will be put into research. The next step is to determine the RPN value by multiplying the severity, occurrence, and detection values. The table below shows analysis of size error reject

Table 2 Rating scale of size error reject

Main Factor	Root cause	S	Process Failure Causes	O	Control	D
Man	Error in dimension interpretation	8	unthorough	8	Training	3
Material	Wrong thickness	7	different material types	6	Clarify inventory tags	4
Method	Oblique plate bending results	5	Too much reference to laser marking	3	inspection checking	4
	Unclear dimensions in the drawings	5	unprepared images	5	Perform image analysis & complete sub comps	5
Machine	Brittle welds	6	scale and dirt on the welding machine	4	Checking and doing machine maintaining	4
	Worn lathe tool	6	Frequent friction	3		3

The next step is to find the RPN value by multiplying the severity of failures (S), the probability of occurrence (O), and the probability of failure detection (D) values whose data is obtained from table 2. Each of the main factors will be calculated and then ranked. The man/human factor is the main contributor to product defects, which means when the operator misinterprets the dimensions, it will cause high product defects. This number becomes higher when the operator sends the incorrect thickness of the material, the method used causes a bending result, and the machine used is already worn out.

Table 3 Risk priority number result

Main Factor	Root cause	RPN	Sum	*Rank*
Man	Error in dimension interpretation	192	192	1
Material	Wrong thickness	168	168	3
Method	Oblique plate bending results	60	185	2
	Unclear dimensions in the drawings	125		
Machine	Brittle welds	96	150	4
	Worn lathe tool	54		

CONCLUSION

The application of the FMEA has led to obtaining two classification errors in the production process; size error and painting error. The most dominant defect is size error that gives a number equal to 73.17%. Of all the contributing factors, four main leading factors contribute to producing defective product. These four factors are man, material, method, and machine. The man/human factor is the main contributor to product defects; it gives an RPN score of 192.

FMEA is a tool that not only helps identify and asses the root cause of reject goods but also affects the overall next year planning by proposing measures to reduce risk. FMEA contributes to the company's future continuous improvement program in terms of quality control that leads to maintaining a company's reputation.

The results of this study imply that there are weaknesses in the standard procedures performed by operators. Therefore, this study's results suggest improving standard operating procedures for production workers and improving operators' skills by providing tiered training.

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