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FAILURE MODE AND EFFECT ANALYSIS FOR IDENTIFYING AND MITIGATING CASING COMPONENT FAILURES AT THE PRODUCTION OF PETROL MINI FUEL STATION

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ABSTRACT

Company "X" is a company that focuses on providing, processing, and distributing steel plates and ready-mix concrete for various industrial fields. This company produces petro mini fuel station called "Pertashop" which consists of main components as modular, canopy and totem. One of the of the most critical components in production failure is the Casing of Pertashop's Modular. This production failure occurs due to the causal factors that arise during the production process and this research was carried out to find out the cause of production failure. This research was conducted by identifying and analyzing the causes of the production failure of Pertashop Casing components using Failure Mode and Effect Analysis. Based in this method, it's miles feasible to understand the severity, feasible reasons, and motive detection values for each production failure. Then, the highest potential causes of failure are ranked. The analysis found that the causes of production failures that are prioritized for immediate repair and suggestions for improvement can be given to the prioritized causes of failure.

Keywords: Failure Mode and Effect Analysis, Fishbone Diagram, Pareto Diagram, Production Failure.

1. INTRODUCTION

Company "X" is a manufacturing company that uses steel or concrete to produce. One of their products is a mini fuel station "Pertashop", which functions the same as gas stations in general, but with a smaller tank size. Pertashop is distributed and operated in the and remote areas of Indonesia. The Pertashop tank has a maximum volume of 3000 liters with a shelter size of 2.4 meters x 2.4 meters x 2.8 meters.

Pertashop are made up of three main components: modular, canopy, and totem. Modular itself consists of several components that are formed through a variety of different production processes. The modular components are the inner tank, outer tank, baseframe, and casing. During the production process, several obstacles were encountered leading to production failure and one of the critical components that often fail is the casing of the Pertashop modular.

The obstacles often occur in casing's component production process. The components of the casing consist of hollow, plate, end close, and ACP support. For example, the condition of a shearing machine with a blunt blade can cause the hollow cut to be damaged or bent, which if the damage exceeds tolerance, the component will become a failed component. In the casing wall welding processed which consists of two or three different plates, errors from the operator when welding can make the connection or joint plate loose and when putty and painted there is a risk of cracking the casing wall. Then, the operator who is not careful in taking measurements can result in the end close cut results and the ACP support not being in accordance with the technical drawings so that these components cannot be joined to the frame of the casing. Production failure causes these components to need repair or even these components cannot be used/rejected.

Based on the production failure that occurred, the company needs to know the factors that caused the failure. It is to avoid the same failure that could happen in the future. So, this production failure can be minimized by making improvements to the causes of these failures. The method used to identify the factors causing the failure of Pertashop Casing component production is Failure Mode and Effect Analysis (FMEA). Using this method, various causes of production failure can be identified. Thus, the objectives of this study are to identify the causes of failure in the production of Pertashop Casing components and to formulate the solutions and suggestion a priority cause of failure for improvements to prevent the failure of Pertashop Casing component production at Company X. The data used are based on the Pertashop daily reports and during production process from January to February 2022.

2. LITERATURE REVIEW

2.1. Production Failure

The production process plays an important role in fulfilling the needs of the customers. The manufacturing process is designed to monitor quality so as not to cause product failure, but in reality, some products still have problems, especially in the manufacturing process (Zonnenshain and Kenett, 2020). A product failure is a product that does not meet the specified standard quality, but it can be economically processed and returned to a good finished product due to the cost of repairs (Ariffin et al., 2018). A defective product is one that does not meet the expectations, goals, or product goals that the company has identified as good and reasonable, and the product does not meet established quality standards (Gharaei, et al., 2020).

2.2. Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a systematic model to identify and prevent a problem that exists in a system (Sharma and Srivastava, 2018). The use of FMEA is carried out with a discussion process from different divisions in the company to analyze the causes of failure of components and subsystems in a process or product. FMEA uses the criteria for occurrence, detection, and severity to determine risk priority numbers (RPN). The method FMEA used to examine the causes of defects or failures that occur during production, evaluate risk priorities, and help determine appropriate actions to avoid identified problems. The stages of applying the FMEA method are as follows (Gueorguiev et al., 2020): (1) Review the process or product; (2) Brainstorm potential failure modes; (3) List the potential impact of each failure mode; (4) Assign a severity rating (S) to each effect that occurs. This value is the level of seriousness of the effect of subsequent component failure; (5) Assign an occurrence rating (O) to each effect that occurs. This value represents the probability or frequency of failure; (6) Assign detection ratings (D) to each effect that occurs. This value represents the degree of inability to detect failure or the likelihood of failure not being detected before its effects manifest; (7) Calculating the Risk Priority Number (RPN) for each effect. RPN is a mathematical product of the severity, frequency, or probability of the occurrence of causes that will result in failure related to the effects and ability to detect failures before they occur; (8) Prioritizing failure modes to be followed up; (9) Take action to eliminate or reduce highrisk failure modes; (10) Calculates the result of risk priority number after failure mode is reduced or eliminated.

$$RPN = S \times O \times D \qquad \dots (1)$$

2.3. Pareto Diagram

Pareto diagram are a way to manage errors, problems, or defects and draw attention to problem-solving efforts (O'Regan and O'Regan, 2019). This diagram/graph is based on the work of 19th century economist Vilfredo Pareto. Joseph M. Juran popularized Pareto's work, noting that 80% of the company's problems were the result of only 20% of the causes. This Pareto diagram is a chart in which the data classification is sorted from left to right in order from the highest rank to the lowest rank. This helps to distinguish between the most important issues that need immediate attention (highest rank) and those that do not need immediate attention (lowest rank). Pareto diagram can also identify key issues that affect quality improvement efforts (Picarillo, 2018).

2.4. Fishbone Diagram

A fishbone diagram helps to identify all symptoms of a business problem because it evaluates the causes and sub-causes of the problem (Rodgers and Oppenheim, 2019). A fishbone diagram is one of seven tools to show the relationship between an effect and its cause. The relationship between the consequences and causes of problems with fish bones is shown in the figure. The main problem is placed on the main bone and the cause of the problem is described in the Fish Bone subsection. There are four areas of cause of a problem: Environment, Personnel, Machinery, and Management.

3. METHODS

The production failure data of the Pertashop Casing component production is obtained from the daily report during production from January to February 2022. The information for the cause of production failure was obtained through direct interviews with production process supervisor, quality control supervisor and operators.

Data analysis was carried out by calculating the Pertashop Casing components failure using Failure Mode and Effect Analysis (FMEA). FMEA generates data that is used to analyze the causes of failures that occur during the Pertashop Casing components production process. FMEA implements the calculation process by providing rating severity, occurrence, and detection values. Then the RPN value is calculated to determine the priority causes of failure. The analysis done based on the Pareto diagram and Fishbone diagram so that suggestions for improvements can be given to reduce the causes of failure in the production of Pertashop Casing components.

4. RESULTS

Table 1 shows the number of Pertashop Casing components production failures that occurred in 2022. The first step that must be done is to determine the system components to be analyzed. For this report, the system being analyzed is Pertashop Casing component production process. Then, identify the type of failure and the causes that arise from the failure mode. Based on the production failure that occurs, identification can be done. The identification of the cause of Pertashop Casing components production failure can be seen in Table 2.

Table 1 Pertashop Casing Components Production Failures in 2022

Pertashops' Chasing Component QTY/50 set		
Components	**Quantity of Component**	**Quantity of failure Component**
Hollow Casing 1-6	700	60
Plate (Case Wall)	850	98
End Close	100	5
Support ACP	400	18

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Table 2 Identification of the Cause of Pertashop Casing Components Production Failure in 2022

Pertashops' Chasing Component QTY/50 set				
No	**Components**	**Production Failure**	**Cause of failure**	**Quantity**
1	Hollow Casing 1-6	Incompatibility of cutting process	Operator error in marking process	5
			Operator error in cutting and positioning	4
		Incompatibility of fitting up process	Welding error	6
			Frame fit up errors and mismatches join result	12
		Dimensional disability	Cuts exceed tolerant	5
			The results of the tenuous join	10
		Visual disability	Welding results prominent and messy	12
			The results of the cut are not neat	6
2	Plate (Case Wall)	Defective material (broken, not straight, cleft)	Operator error in material transport	3
			Excessive pile of material in transport	6
		Incompatibility of cutting process	Operator error in marking process	8
			Operator error in marking and punching positioning	4
		Untidy cuts and fring	Blunt cutting knife	5
			Operator error in grinding proces	11
		Incompatibility of fitting up process	Welding error	7
			Plate fit up errors and mismatches join results	16
		Dimensional disability	Cuts excedd tolerant	11
			The results of the tenuous join	8
		Visual disability	Welding results prominent and messy	7
			The results of the cut are not neat	5
3	End Close	Incompatibility of cutting process	Operator error in marking process	5
4	Support ACP		Operator error in cutting and punching positioning	18

Based on the results of identification of production failures that occur, data processing can be carried out. First, the severity rate is determined. The severity rate is determined based on the consequences of the failure. Next, processing the data by determining the occurrence rate. The determination of the occurrence rate is given based on the frequency of failures due to these causes. Then, processing the data by determining the detection rate. Determination of the detection rate is given based on the probability of failure not detected before the effect becomes apparent. If an assessment has been made for each failure mode, RPN can be calculated. RPN values for each production failure is presented on Table 3.

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Table 3 RPN of Pertashop Casing Components Production Failure in 2022

Pertashops's Chasing Component QTY/50 set								
No	**Components**	**Production Failure**	**Cause of failure**	**Qty**	**S**	**O**	**D**	**RPN**
1	Hollow Casing 1-6	Incompatibility of cutting process	Operator error in marking process	5	2	5	2	20
			Operator error in cutting and positioning	4	2	5	2	20
		Incompatibility of fitting up process	Welding error	6	4	6	2	48
			Frame fit up errors and mismatches join result	12	5	6	3	90
		Dimensional disability	Cuts exceed tolerant	5	3	5	3	45
			The results of the tenuous join	10	5	6	4	120
		Visual disability	Welding results prominent and messy	12	4	6	4	96
			The results of the cut are not neat	6	4	5	2	40
2	Plate (Case Wall)	Defective material (broken, not straight, cleft)	Operator error in material transport	3	1	5	4	20
			Excessive pile of material in transport	6	1	5	4	20
		Incompatibility of cutting process	Operator error in marking process	8	4	5	2	40
			Operator error in marking and punching positioning	4	2	5	2	20
		Untidy cuts and fring	Blunt cutting knife	5	2	5	2	20
			Operator error in grinding proces	11	4	6	4	96
		Incompatibility of fitting up process	Welding error	7	4	5	2	40
			Plate fit up errors and mismatches join results	16	5	6	4	120
		Dimensional disability	Cuts excedd tolerant	11	3	6	3	54
			The results of the tenuous join	8	5	5	4	100
		Visual disability	Welding results prominent and messy	7	4	6	4	96
			The results of the cut are not neat	5	4	5	2	40
3	End Close	Incompatibility of cutting process	Operator error in marking process	5	4	7	2	56
4	Support ACP		Operator error in cutting and punching positioning	18	2	7	2	28

Based on the known RPN values, these values are in order of the largest value. This ordering of values can help identify the type of product failure that has the most impact on production yields. Table 4 shows the sequences RPN values.

Table 4 Sequential RPN of Pertashop Casing Components Production Failure in 2022

Pertashops's Chasing Component QTY/50 set							
No	**Components**	**Production Failure**	**Cause of failure**	**Qty**	**RPN**	**Failure Percentage (%)**	**Cummulative Failure Percentage (%)**
1	Hollow Casing 1-6	Dimensional disability	The results of the tenuous join	10	120	10%	10%
2	Plate (Case Wall)	Incompatibility of fitting up process	Plate fit up errors and mismatches join results	16	120	10%	20%
3	Plate (Case Wall)	Dimensional disability	The results of the tenuous join	8	100	8%	28%
4	Hollow Casing 1-6	Visual disability	Welding results prominent and messy	12	96	8%	35%
5	Plate (Case Wall)	Untidy cuts and fring	Operator error in grinding proces	11	96	8%	43%
6	Plate (Case Wall)	Visual disability	Welding results prominent and messy	7	96	8%	51%
7	Hollow Casing 1-6	Incompatibility of fitting up process	Frame fit up errors and mismatches join result	12	90	7%	58%
8	End Close	Incompatibility of cutting process	Operator error in marking process	5	56	5%	635
9	Plate (Case Wall)	Dimensional disability	Cuts excedd tolerant	11	54	4%	67%
10	Hollow Casing 1-6	Incompatibility of fitting up process	Welding error	6	48	4%	71%
11	Hollow Casing 1-6	Dimensional disability	Cuts exceed tolerant	5	45	4%	75%
12	Hollow Casing 1-6	Visual disability	The results of the cut are not neat	6	40	3%	78%
13	Plate (Case Wall)	Incompatibility of cutting process	Operator error in marking process	8	40	3%	815
14	Plate (Case Wall)	Incompatibility of fitting up process	Welding error	7	40	3%	855
15	Plate (Case Wall)	Visual disability	The results of the cut are not neat	5	40	3%	88%
16	Support ACP	Incompatibility of cutting process	Operator error in cutting and punching positioning	18	28	2%	90%
17	Hollow Casing 1-6	Incompatibility of cutting process	Operator error in marking process	5	20	2%	92%
18	Hollow Casing 1-6	Incompatibility of cutting process	Operator error in cutting and positioning	4	20	2%	93%

Pertashops' Chasing Component QTY/50 set							
No	**Components**	**Production Failure**	**Cause of failure**	**Qty**	**RPN**	**Failure Percentage (%)**	**Cummulative Failure Percentage (%)**
19	Plate (Case Wall)	Defective material (broken, not straight, cleft)	Operator error in material transport	3	20	2%	95%
20	Plate (Case Wall)	Defective material (broken, not straight, cleft)	Excessive pile of material in transport	6	20	2%	97%
21	Plate (Case Wall)	Incompatibility of cutting process	Operator error in marking and punching positioning	4	20	2%	98%
22	Plate (Case Wall)	Untidy cuts and fring	Blunt cutting knife	5	20	2%	100

In the order of RPN values, each product failure is converted into a percentage. This percentage is a big picture of the consequences of product failure. The percentage value of the RPN is shown in the form of a Pareto diagram while identifying the root cause can be done by making a cause-and-effect diagram shown in the form of a Fishbone diagram. Pareto diagram shows from the biggest failures that occurred during the production process. Pareto diagram and Fishbone diagram of a production failure are presented on Figure 1 and Figure 2.

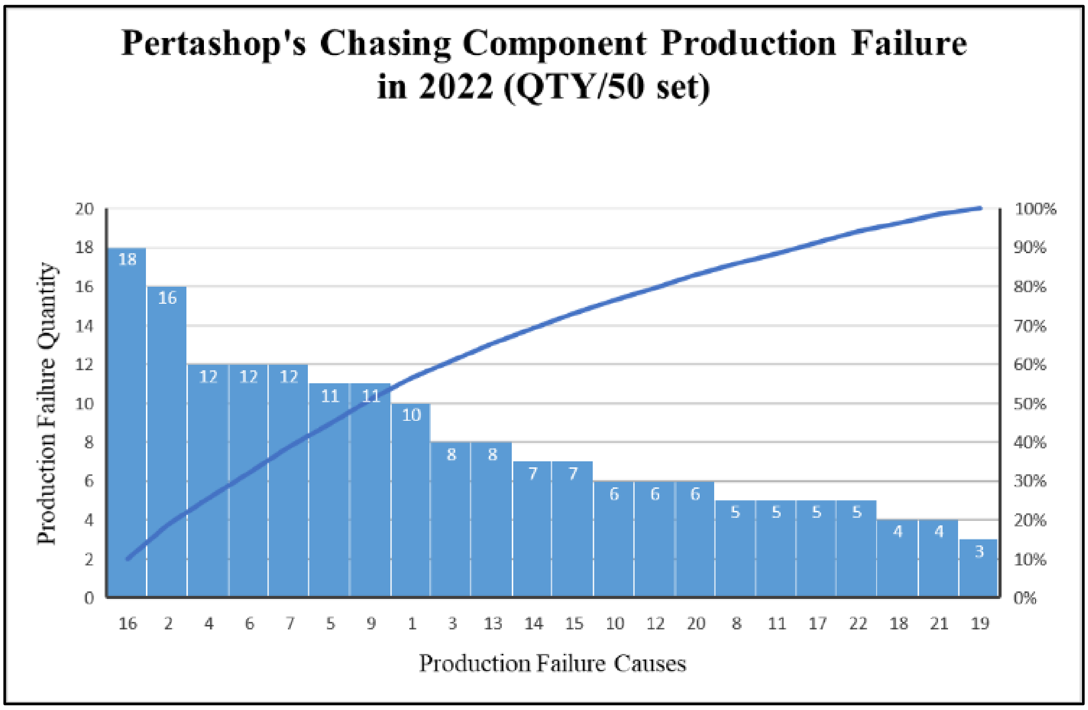

Figure 1. Pareto Diagram of Pertashop Casing Components Production Failure in 2022

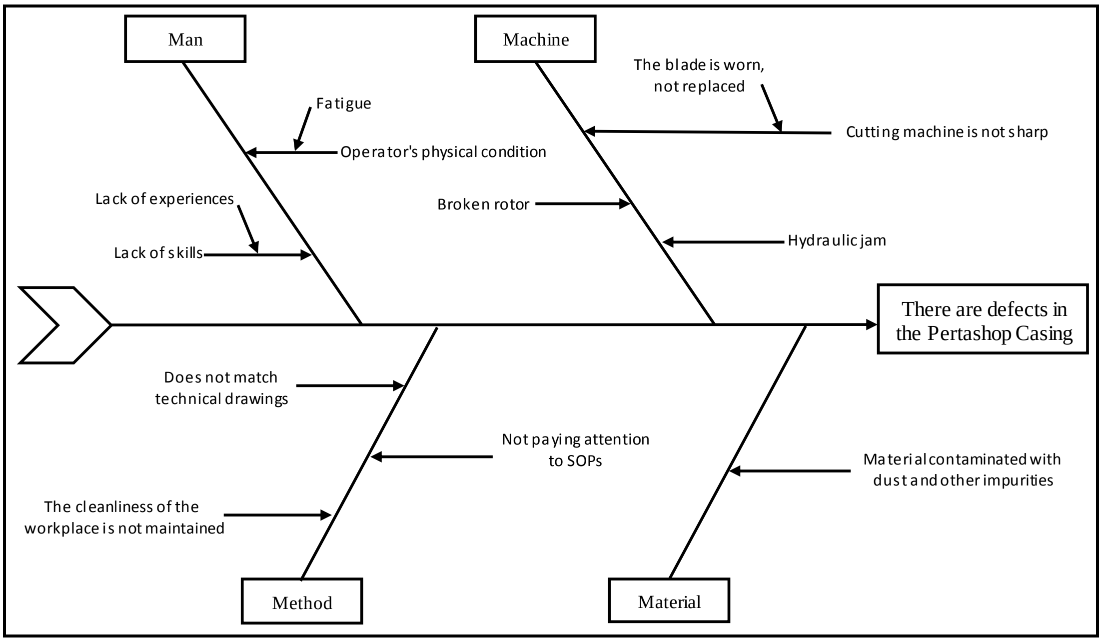

Figure 2. Fishbone Diagram of Pertashop Casing Components Production Failure in 2022

5. DISCUSSION

The results show the various factors causing the failure of Pertashop Casing production in 2022. Data processing is carried out based on the steps to complete the FMEA. The FMEA method applies a RPN calculation process based on severity, occurrence, and detection values. The RPN value obtained in each component failure mode indicates that the higher the RPN value, the higher the priority for repair needs.

The RPN calculation is done based on the cause of the failure mode. The higher the severity rating, the more dangerous due to failure and contrary to safety regulations. The higher the occurrence rating, the more likely the failure mode will occur. The higher the detection rating, the more difficult it is to detect the failure mode (Chang et al., 2021). The highest RPN value in the failure of production of Pertashop Casing components is dimensional disability in hollow casing manufacturing due to the result of the tenuous join.

Pareto diagram shows all failure modes of the Pertashop Casing components production process in 2022. The higher the percentage, the higher the probability of product failure. The high production failure rate led to immediate repairs. There are twenty-two causes of failure in Pertashop Casing production with twelve critical causes. Twelve critical causes of failure are the result of the tenuous join in hollow casing, plate fit up errors and mismatches join results, the result of the tenuous join in plate, welding results prominent and messy in hollow casing, operator error in grinding process in plate, welding results prominent and messy in plate, frame fit up errors and mismatches join results, operator error in marking process in end close, cuts exceed tolerant in plate, welding error in hollow casing, cuts exceed tolerant in hollow casing, and the results of the cut are not neat in hollow casing. Then the cause of production failure must be immediately followed up for improvement, in order to increase work effectiveness and avoid work accidents.

The cause of a problem is identified by creating a cause-and-effect diagram, or commonly referred to as a Fishbone diagram. Fishbone diagram are useful in Pertashop to identify factors that are causing failures during case manufacturing. Factors considered include human factors, machines, environments and methods. From the human factors side, the failure can be caused by lack of operators' skills and operator's physical condition. While from machine side, it was probably caused by hydraulic jam, broken rotor, or blunt cutting machine. Otherwise, from method side, the failure can be caused by unmatching of technical drawings, not paying attention to SOPs, or the cleanliness of the workplace is not maintained. Later, from material side it can be caused by the contamination of materials with impurities.

Proposed improvements to the occurance of failures are:
(1) Make a clear SOPs for operators;
(2) Regular maintenance of machines;
(3) Choose expert operators in their fields;
(4) Adding manpower;
(5) Inspect and clean raw materials from dust and dirt.

6. CONCLUSION

There are 22 causes of Pertashop Casing components production failures IN Company X. The production failure can be categorized as incompatibility of cutting process, incompatibility of fitting up process, dimensional disability, visual disability, defective material (broken, not straight, cleft), and untidy cuts and fringe. Twelve priority or critical causes of Pertashop Casing components production failures are the result of the tenuous join in hollow casing, plate fit up errors and mismatches join results, the result of the tenuous join in plate, welding results prominent and messy in hollow casing, operator error in grinding process in plate, welding results prominent and messy in plate, frame fit up errors and mismatches join results, operator error in marking process in end close, cuts exceed tolerant in plate, welding error in hollow casing, cuts exceed tolerant in hollow casing, and the results of the cut are not neat in hollow casing.

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