

Risk Analysis of Component Quality in the Production Process of Gate Valves Using the Failure Mode and Effect Analysis Method

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ABSTRACT

Material damage is a common occurrence in every production in a company, of course material damage is very often found in the Quality Control process in every manufacturing company. Especially in the company I do internship there are four production production sections in the burr and stamp process, namely: structure division, finishing division, assembly division, packaging division. The one that often experiences damage problems in the burr and stamp process is the structure division and can still be reworked depending on the level of material damage, based on the largest percentage of products that are most hampered are in the process of stamping material identity details with stamping machines and stamping several material letters without stamp machines, namely by manual tapping or carving processes. The company wants to reduce the addition of rework that makes delivery to customers delayed and not according to shipping estimates. Therefore, the Failure Mode and Effect Analysis (FMEA) method will be used. The stages carried out using the FMEA method are identifying failure modes, identifying the effects of failure, identifying cause effects, determining severity rating values, occurrence rating values, determining current control, detection values, and calculating the Risk Priority Number (RPN) to determine the cause of the damage problem

INTRODUCTION

Every manufacturing company must be aware of the changing customer orientation towards quality. In the increasingly tight competition in the industrial world, companies are required to survive and compete with similar companies. Therefore, companies must be able to meet customer desires and strive to retain customers. The company's commitment to continuously maintain quality is implemented through the adoption of an ISO (International Organization for Standardization) quality management system within the company. However, companies cannot simply stop because, in reality, there are still products that do not meet the standards or specifications applied or defective products. The quality of a product is one of the important factors in business. Quality is closely related to consumer interest in the products to be made, thus requiring a production process that can minimize risk (Risk management to produce quality products in accordance with company standards. The quality that needs to be considered is not just the quality of the final product, but also the production process or products that are still in process (work in progress), so that if defects or errors are detected, they can still be corrected. In the production process, risks can occur in various aspects, such as costs, time, difficulties in making corrections and re-managing risks, and impacts on business continuity over a certain period if production errors occur frequently.

The company where I am interning is a manufacturing company that produces equipment for the oil & gas sector. The products produced include materials such as Gate Valves, Casing Heads, Spools, Casing Hangers, Tubing Hangers, and Bonnet. This research focuses on the material components of Gate Valves. A Gate Valve is a type of material that controls the flow (fluid) and pressure within a system or process through mechanisms of opening, closing, reducing, or increasing the flow. Gate Valves are an important component in piping systems that carry fluids, gases, steam, etc. The functions of a Gate Valve include stopping and starting the flow, reducing and increasing the flow, controlling the direction of flow, and regulating process flow pressure. In the production process, defective products are often encountered.

These defective products must undergo rework to meet company standards. However, this repair process requires additional time, causing delays in production completion, and may even exceed the established deadlines. If there are still many damages occurring in the production process, it will affect the production costs incurred by the company. Therefore, the author finds it important to conduct an analysis of the risks that arise during the production process and to seek solutions that can be implemented to minimize product defects. The purpose of this research is to identify the types of damages that most affect product quality, estimate the total costs produced from the production process, and provide proposals for improvements in the production process to reduce failure rates and increase cost efficiency.

The aim of this research is to improve the overall quality and quantity of data concretely from various issues and causes of processing failures, and the reason for this study is to support the enhancement of knowledge to better understand

and identify the root causes of failure in a material component processing process.

LITERATURE REVIEW

According to Villacourt (1992), Fault Mode Effect Analysis (FMEA) is an engineering technique used to establish, identify, and eliminate known failures, problems, errors, and similar issues from a system, design, process, or service before reaching the consumer. The purpose of using FMEA is to analyze the product design characteristics in relation to the planned manufacturing process and design experiments to ensure that the produced products meet customer needs and expectations. When potential failure modes are identified, corrective actions can be taken to eliminate them or to continue reducing the potential occurrence. FMEA also documents the reasons for the chosen manufacturing process. It provides an organized critical analysis of potential failure modes and associated causes for a defined system. This technique uses occurrence and detection probabilities along with severity criteria to develop a Risk Priority Number (RPN) to rank corrective action considerations. The purpose of this research is to determine the type of material to be analyzed and the types of failures or damage caused to the material, as well as to identify the factors or causes of failures that occur during the processing of the Gate Valve material, and to address the failures that arise in the process.

METHODOLOGY

This research was conducted at my internship place, which operates in the manufacturing of oil & gas equipment. One of the materials produced is the Gate Valve. The first stage of this research is the preparation stage. This preparation stage is divided into five sequences, including observation, interviews, problem formulation, research objectives and benefits formulation, and literature review. The next stage is data collection. In this data collection stage, it is divided into three: primary data, secondary data, and questionnaire distribution. Primary data is data obtained directly from respondents and collected through field surveys using direct data collection techniques through interviews with the production head at my internship. Secondary data is data obtained indirectly, such as from archival material damage records over the past three months (September 2024 – November 2024) that owned by the company

There are four secondary data points needed in this study, namely the historical average production volume in one month, the cost of defective materials, data on labor wages each month, and the costs of losses due to defective products. The third stage of data collection is through distributing questionnaires to 7 employees in the production department where I intern, all with over 3 years of experience. The attributes present in this questionnaire are derived from interviews conducted with the production head regarding the sequences of the production processes, as well as potential risks that may occur. This questionnaire aims to determine the values of severity, occurrence, and

detection in the production process. These values (severity, occurrence, detection) will be used to assess the risks that occur in the production process.

1. Observation

The first stage is to conduct observations by observing several forms of failures that result in damage and analyzing the damage problems present in the production process of Gate Valve materials at the company where I am interning.

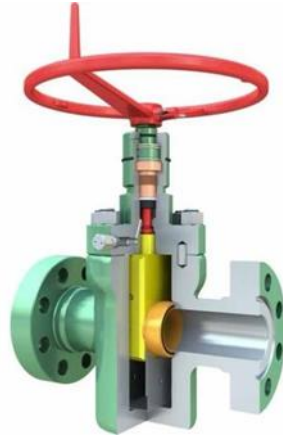


Figure 1. Isometric View of Material Gate Valve

2. Collection of Primary Data

Primary data is information gathered directly from primary sources through field observation. Data collection is carried out using direct interview techniques, where the researcher interacts face-to-face with the production manager at my internship location to gain an in-depth understanding of the production process. This method allows the researcher to capture reality in the field more accurately and contextually.

3. Collection of Secondary Data

In this study, secondary data was obtained through indirect sources, including the company's internal archives that recorded product failures during the last quarter (September to November 2024). Additional information analyzed included large-scale operational data, such as average monthly production output, a list of materials that experienced quality deviations, monthly labor expenditure trends, and estimates of economic losses due to defective products. The analysis was conducted comprehensively to trace the relationship between the effectiveness of the production process, the quality of raw materials, and the cost consequences of quality control activities.

4. Dissemination of Questionnaires

The third stage of data collection involved distributing questionnaires to 7 production employees with more than 3 years of work experience. The attributes in this questionnaire were derived from interviews conducted with the production head regarding the order of production processes and the potential risks that may arise. This questionnaire aims to understand the values of severity, occurrence, and detection in the production process. These values (severity, occurrence, detection) will be used to assess the risks that occur in the production process.

5. Establishing the Values (S.O.D) Severity, Occurrence, Detection and Determining (RPN) Risk Priority Number

In determining the values of Severity, Occurrence, and Detection, references are made to the IEC 60812 standard published by the IEC (International Electrotechnical Commission), titled 'Analysis Techniques for System Reliability – Procedure for Failure Mode and Effects Analysis (FMEA)' in 2018. IEC 60812 is a widely used general guideline across various industries, including manufacturing and the oil and gas sector. The steps of FMEA in this study (identifying failure modes, effects, causes, as well as assessing severity, occurrence, and detection) align with the procedures outlined in IEC 60812. The assessment of severity in the production process relates to how likely a product failure is to occur during that process. In this assessment, there are ten ratings for severity which

Table 1. Severity of Effect in FMEA Process

Impact	Severity Level of Impact	rate
Dangerous without warning	Failure is not preceded by warning.	10
Dangerous with a warning	Failure is preceded by warning.	9
Very high	The product cannot be used.	8
High	The product can be used with a risk of failure for high functions.	7
Currently	The product can be used even if the product appearance is not good.	6
Low	The product can be used without affecting its function.	5
Very Low	Defects are acknowledged by the customers. (>75%)	4
Minor	Defects are acknowledged by the customers. (>50%)	3
very minor	Defects are acknowledged by the customers. (>25%)	2
None	Has no influence	1

The assessment of occurrence is carried out to determine how often product failures occur during the production process. Similar to the assessment of severity, the evaluation of the likelihood of failure occurrence can also be conducted through the distribution of questionnaires to employees in the production department. This assessment is done by asking respondents to provide a score in the range of 1 to 10, aimed at measuring the probability of a failure occurring in the production process.

Table 2. Occurrence Rating in the FMEA Process

Probability of Risk Occurrence	Frequency	Rank
Very High	≥ 1 in 3	10
High	1 in 5	9
	1 in 10	8
	1 in 20	7
Currently	1 in 50	6
	1 in 75	5
	1 in 100	4
Low	1 in 200	3
	1 in 500	2
Very Low	Failure can be eliminated.	1

The assessment of Detection aims to determine how likely failures can be detected to the maximum extent. The same applies to severity and occurrence. To determine the value of detection, a questionnaire must also be distributed to production department employees. Detection has a range from 1 to 10, where a score of 1 means that the risk of product failure is very likely to be detected, while a score of 10 means that the risk of product failure is very difficult to detect by the controller.

Table 3. Detection Rating in the FMEA Process

Detection	Detection Probability	Rank
Almost impossible	The controller cannot detect the failure.	10
Very rarely	It is very unlikely that the controller will find potential failures.	9
rarely	It is unlikely that the controller will find potential failures.	8
very Low	The likelihood of the controller detecting a failure is very low.	7
Low	The controller is likely to detect low failures.	6
Currently	The controller is likely to detect a moderate failure.	5
Quite High	The likelihood of the controller detecting a failure is quite high.	4
High	The controller is likely to detect high failures.	3
Very High	The likelihood of the controller detecting a failure is very high.	2
Almost certainly	Failure in the process is unlikely to occur because it has been prevented with a solution.	1

After the values of severity, occurrence, and detection for each process are determined, the next step is to calculate the Risk Priority Number (RPN). The formula for RPN is: $RPN = \text{severity} \times \text{occurrence} \times \text{detection}$. After that, it is necessary to calculate the probability impact matrix by comparing the results of the survey between severity and occurrence.

Table 4. Gate Valve Questionnaire Table

No	Gate Valve Components	Component Function	Type of Risk	rate Severity	rate Occurrence	rate Detection
1	<i>Stem Nut</i>	As the stem rotates according to its thread.	Worn thread rod			
2	<i>Stem</i>	For the actuator to open and close the valve connected between the hand wheel and the disc.	Wet branch Bend			
3	<i>Disc</i>	The most important primary pressure limit is as the opener and closer of the flow.	Corrosion			
			Leaking			
			Worn away			
4	<i>Seat</i>	As the surface for the disc seat	Corrosion			
			Leaking			
			Worn away			
5	<i>Hand Wheel</i>	To operate opening and closing the gate valve.	Loose			
			Broken			
6	<i>Gland Packing</i>	As a tightening device for the packing position to adhere closely to the stem..	Leaking			
			Loose			
7	<i>Packing</i>	As a seal guard on the gap between the stem and the bonnet to prevent leakage..	Leaking			
			Packing Aus			
8	<i>Gasket</i>	As a connector between the valve body and the bonnet to prevent leaks.	Leaking			
			Broken Gasket			

After the creation of the questionnaire table with important components in determining the quality risk of Gate Valves, the next step was to distribute the questionnaire to 7 employees with more than 3 years of work experience at the company where I interned

3. Data Analysis and Discussion

Definition of Gate Valve System Functions

The definition of the Gate Valve function hierarchy was carried out by grouping system and subsystem functions at the component level so that they are logically related within that hierarchy. The hierarchy of the Gate Valve system functions is shown in

Table 5. Gate Valve Identification Table

ID system	system	ID Sub-system	Sub-system	ID Component	Component
1	Gate Valve	1.1	Axis	1.1	Stem Nut
				1.2	Stem
			Driving Machine	2.1	Disc
				2.2	Seat
			Lever Control	3.1	Hand Wheel
			Contact Remains	4.1	Gland Packing
				4.2	Packing
				4.3	Gasket

RESULTS AND DISCUSSION

Results of RPN Value Calculation

The first calculation performed is the RPN (Risk Priority Number) calculation. The RPN calculation has the following formula: $RPN = \text{severity} \times \text{occurrence} \times \text{detection}$. In this questionnaire, it is known that there are 17 types of risks from 8 components that make up the Gate Valve, and a questionnaire was distributed to 7 employees each to determine the average values of severity, occurrence, and detection. FMEA identifies each failure mode that could lead to functional failure in the Gate Valve system components. An average value was obtained. The FMEA calculation table can be shown in

Table 6. Questionnaire Results Table (Severity, Occurrence, Detection)

No	Component	Type of Risk for each component	The effects caused	Severity (S)	Causes of Material Defects	Occurrence (O)	The control that is carried out	Detection (D)	RPN
1	Stem Nut	Worn thread rod	Operations are disrupted	4.9	Operation is not correct	3.4	Controlling the cleanliness of the Stem	3.3	55.0
Total RPN									55.0
2	Stem	Wet stem	Experiencing a leak	4.3	Age of Stem	3.3	Controlling Stem	3.3	46.6
		Bend	Flow out	5.3	Age of Stem	4.7	Controlling and providing lubrication	3.3	82.5
Total RPN									129.1
3	Disc	Disc Corrosion	Uncontrolled flow	6.4	There is a leak.	5.7	Controlling the condition	3.7	135.3
		Disc Leaking	Uncontrolled flow	7.3	Disc aus	6.9	Controlling the Disc condition	4.1	205.2
		Disc Worn away	Weak flow	6.1	There was friction	4.9	Controlling the Disc condition	3.4	100.7
Total RPN									441.3
4	Seat	Seat Corrosion	Uncontrolled flow	6.3	There is a leak.	5.6	Controlling the Seat condition	3.6	126.4
		Seat Leaking	Uncontrolled flow	7.1	Seat aus	6.7	Controlling the Seat condition	3.9	185.9
		Seat Worn away	Weak Flow	6.4	There was friction	5.0	Controlling the Seat condition	3.3	105.6
Total RPN									417.9

4	Seat	Seat Corrosion	Uncontrolled flow	6.3	There is a leak.	5.6	Controlling the Seat condition	3.6	126.4
		Seat Leaking	Uncontrolled flow	7.1	Seat aus	6.7	Controlling the Seat condition	3.9	185.9
		Seat Worn away	Weak Flow	6.4	There was friction	5.0	Controlling the Seat condition	3.3	105.6
Total RPN									417.9
5	Hand Wheel	Hand Wheel Loose	The opening and closing is not perfect	4.7	Insufficient lubrication	3.9	Controlling and performing lubrication	3.4	61.6
		Hand Wheel broken	Cannot open and close the valve.	5.7	Cannot open and close the valve.	4.3	Controlling the Hand Wheel	3.3	80.6
Total RPN									142.3
6	Gland Packing	Gland Packing Leaking	The bolt is loose.	5.9	Age Gland Packing	4.1	Controlling the tightness of the bolts	3.4	83.1
		Gland Packing Loose	Packing Loose	5.1	There has been loosening.	4.0	Controlling additional grease	3.3	67.3
Total RPN									150.4
7	Packing	Packing Leaking	Flow out	5.0	Age Packing	4.7	Controlling the tension Packing	3.4	80.1
		Packing Aus	Experiencing a leak	3.9	Age Packing	3.3	Controlling Packing	3.3	42.3
Total RPN									122.4
8	Gasket	Gasket leaking	Flow out	6.0	Age Gasket	4.7	Controlling the tightness of the bolts	3.4	96.2
		Gasket Broken	Flow out	5.3	Age Gasket	5.0	Controlling the tightness of the bolts	3.4	87.5
Total RPN									183.6

Based on the results of the RPN calculation data obtained, the next step is to determine the order starting from the most critical risk (the highest RPN value) to the lowest based on 17 types of risks of the components that make up the Gate Valve. The results of the ranking from highest to lowest RPN per type of risk can be seen in

Table 7. Ranking Table from Highest to Lowest RPN per Risk

No	Component	Types of Product Defects	High-Low Order RPN by Risk
1	Disc	Disc Leaking	205.2
2	Seat	Seat Leaking	185.9
3	Disc	Disc Corrosion	135.3
4	Seat	Seat Corrosion	126.4
5	Seat	Seat Worn away	105.6
6	Disc	Disc Worn away	100.7
7	Gasket	Gasket Leaking	96.2
8	Gasket	Gasket Broken	87.5
9	Gland packing	Gland packing Leaking	83.1
10	Stem	Stem Bengkok	82.5
11	Hand wheel	Hand wheel Broken	80.6
12	Packing	Packing Leaking	80.1
13	Gland packing	Gland packing Loose	67.3
14	Hand wheel	Hand wheel Loose	61.6
15	Stem nut	Threaded rod aus	55
16	Stem	Trunk aus	46.6
17	Packing	Packing aus	42.3

Then, it can also be determined the order starting from the most critical risk (the highest RPN value) to the lowest based on the 8 components that make up the Gate Valve, after obtaining the total RPN value per component. The results of the ranking from highest to lowest total RPN per component can be seen in Table 8.

Table 8. Table of Ranking From Highest to Lowest Total RPN Per Component

No	Component	Total RPN High-Low Order
1	Disc	441.3
2	Seat	417.9
3	Gasket	183.6
4	Gland Packing	150.4
5	Hand Wheel	142.3
6	Stem	129.1
7	Packing	122.4
8	Stem Nut	55

Results of the Probability Impact Matrix Calculation

According to Hoseynabadi (2010), the probability impact matrix is one of the risk detection methods in the production process aimed at determining the priority risk areas by considering the severity and occurrence values. To calculate this average, one needs to sum all the presented data and then divide it by the total number of data points. In formulaic terms, the method to find the average is: Average = sum of all data ÷ number of data points. The average values of severity and occurrence in this probability impact matrix assessment system are entered by rounding up to the nearest whole number for decimal values greater

than or equal to 0.5 (≥ 0.5) and rounding down for decimal values less than 0.5 (< 0.5). Table 6 represents the average values of the severity and occurrence criteria that serve as inputs for the probability impact matrix.. Table 9 2 is the average value of severity and occurrence for 17 types of product risks according to the results of the questionnaire recap.

Table 9. Table of Average Severity and Occurrence Values

No	Component	Types of Product Defects	Average Severity	Average Occurrence
1	<i>Stem Nut</i>	Worn thread rod	4.9	3.4
2	<i>Stem</i>	Wet stem	4.3	3.3
		Bend	5.3	4.7
3	<i>Disc</i>	Corrosion	6.4	5.7
		Leaking	7.3	6.9
		Worn away	6.1	4.9
4	<i>Seat</i>	Corrosion	6.3	5.6
		Leaking	7.1	6.7
		Worn away	6.4	5.0
5	<i>Hand Wheel</i>	loose	4.7	3.9
		Broken	5.7	4.3
6	<i>Gland Packing</i>	Leaking	5.9	4.1
		loose	5.1	4.0
7	<i>Packing</i>	Leaking	5	4.7
		Packing Aus	3.9	3.3
8	<i>Gasket</i>	Leaking	6	4.7
		Gasket Pecah	5.3	5.0

Then at the risk assessment level with a probability impact matrix, there are five classification levels, namely very low, low, medium, high, and very high. Each level has its own range for assessing impact and probability. Table 10 is a semi-quantitative risk analysis instrument that combines impact (Severity) and probability (Occurrence) parameters to classify risks into five levels. This method aims to systematically map risks so that companies or individuals can determine mitigation priorities based on the scores generated. Key Components:

1. Impact (Severity): Measures the extent of loss or consequences that arise if the risk occurs. A scale of 1-10 is used, where values of 1-4 indicate minimal impact (e.g., minor operational disruptions), while 9-10 represent critical impact (e.g., significant financial loss or reputation loss).
2. Probability (Occurrence): Assessing the likelihood of a risk occurring within a certain period. This 1-10 scale is relative: a low value (1-4) indicates a rare event, while a high value (9-10) indicates an almost certain frequency.

Table 10. Risk Assessment Level Table

Rank	Impact	Probability
Very Low	1-4	1-4
Low	5	5
Currently	6	6
High	7-8	7-8
Very High	9-10	9-10

Table 11. Results of Classification of Each Risk Using the Probability Impact Matrix

Probabilities	Very high					
	High				Disc-Leaking Seat-Leaking	
	Currently			Disc-Corrosion Seat-Corrosion		
	Low	Stem-Wet stem StemNut-Worn thread rod	Gasket-Broken Packing-Leaking Stem-Bend	Gasket-Leaking Disc-Worn Away Seat-Worn Away		
	Ver Low	Packing-Aus	Hand Wheel-Loose Gland Packing-Loose	Gland Packing-Leaking Hand Wheel-Broken		
		Very Low	Low	Currently	High	Very High
		Impact				

Average value :

Impact = Severity

Probability = Occurrence

From the results of the probability impact matrix assessment based on Table 10, we can obtain the production defect items classified in Table 11. There are two types of component defect risks that are classified as critical (high) according to the probability impact matrix assessment, namely the Disc component for the Leak risk type (3) and the Seat component for the Leak risk type (4). Additionally, there are 2 types of product defects with medium impact and probability, which are the Disc component for the corrosion risk type (3) and the Seat component for the corrosion risk type (4). To reduce the level of risk and

product failure rates, risk mitigation needs to be conducted for the two production defects from each component classified as critical and medium.

Comparison of RPN Result Values and Probability Impact Matrix

number (RPN) and probability impact matrix, subsequently the results of these calculations will be compared to identify product defects that are categorized as critical. From the calculations using the RPN method, there are four components that have a risk categorized as critical (high), which are first on the component Disc (Leak) (3), Seat (Leak) (4), Disc (Corrosion) (3), Seat (Corrosion) (4). In the probability impact matrix calculation, there are two product defects categorized as critical (high), namely in the component Disc (Leak) (3) and in the component Seat (Leak) (4). These two methods have different numbers of assessments for product defects that are categorized as critical. In the RPN method, there are four product defects categorized as critical, but in the probability impact matrix, there are two types of product defects categorized as critical. This is due to the difference in calculation methods for these two values, where the RPN value calculation uses the multiplication technique of severity, occurrence, and detection, Meanwhile, the probability impact matrix only requires the average values of severity and occurrence to determine the level of risk assessment.

Table 12. Comparison of RPN Values and Probability Impact Matrix

No.	Types of Product Defects	RPN	Probability Impact Matrix
1	<i>Disc (Leaking)</i>	√	√
2	<i>Seat (Leaking)</i>	√	√
3	<i>Disc (Corrosion)</i>	√	-
4	<i>Seat (Corrosion)</i>	√	-

It can be seen in Table 12 the comparison of the two methods RPN and probability impact matrix, the results using the RPN method found four product defects, namely Disc (Leak), Seat (Leak), Disc (Corrosion), Seat (Corrosion) which are classified as critical (high) product defects compared to using the probability impact matrix which found two product defects that are classified as critical (high), namely Disc (Leak) and Seat (Leak) while the two product defects, namely Disc (Corrosion) and Seat (Corrosion) are not classified as critical (high) defects in this method.

FMEA Cost Based Calculation

In a cost-based FMEA table, there are input and output columns. The input column consists of Re-occurring (the number of recurring failure events), failure frequency, detection time, repair time, delay time, loss time (time wasted due to failure), quantity, and parts cost. Meanwhile, the output column contains three costs, including labor cost, material cost, and opportunity cost. The last

column is the expected failure cost, or the costs arising from failures. Methodologically, the values for Re-occurring, failure frequency, detection time, repair time, delay time, quantity, and parts cost are sourced from primary data obtained through semi-structured interviews with the head of production. Meanwhile, loss time is a measurable variable derived through the specific equation:

$$\text{Loss Time} = (\text{detection time} + \text{repair time} + \text{delay}).$$

As for filling in labor cost, material cost, and the opportunity costs in the output column are generated through the following formula:

$$\begin{aligned} \text{Labor Cost} &= \text{Frequency} \times \{[\text{Detection Time} \times \text{labor wage} \times \# \text{ Operators}] \\ &+ [\text{Repair Time} \times \text{labor wage} \times \# \text{ Operators} \times \text{Quantity}] + [\text{Delay Time} \times \text{labor} \\ &\text{wage} \times \# \text{ Operators}]\} \\ \text{Material Cost} &= \text{Frequency} \times \text{Re-occurring} \times \text{quantity} \times \\ &\text{Parts cost} \\ \text{Opportunity Cost} &= \text{Loss time} \times \text{Opportunity cost} \end{aligned}$$

$$\text{Expected failure cost} = \sum_{i=1}^n p_i c_i \text{ Dimana:}$$

p: The probability of failure that occurs

c: The cost caused by failure

n: The number of failures

$$\text{Value} = \frac{\text{Average Value per type of risk (over 3 months)}}{\text{Total Average Reject Value (over 3 months)}} \times 100$$

The Re-Occurring Value in Table 13 is assigned a value of 1 because it is assumed that each product failure that occurs only requires one replacement or repair of material for each frequency of failure. In other words, each time a failure occurs (according to frequency), the material cost incurred is for one action of repairing or replacing the damaged part. Other data obtained during the interview process include the monthly wage of labor amounting to Rp4,685,050/month or labor wages of Rp22,500/hour, in addition to data regarding the opportunity cost obtained which is Rp190,000/hour. Expected Failure Cost = Labor Cost + Material Cost + Opportunity Cost

Table 13. FMEA Cost Based Calculation

No Resiko	Input								Output			Biaya Ekspektasi Kegagalan (Rp)
	Re-occurring	Frekuensi	Waktu Deteksi (jam)	Waktu Perbaikan (jam)	Waktu Pengadaan (jam)	Loss Time (jam)	Kuantitas	Part Cost (Rp)	Biaya Tenaga Kerja (Rp)	Biaya Material (Rp)	Biaya Kesempatan (Rp)	
3.2 (Disc Bocor)	1	9	0.28	1.00	0.75	2.03	4.67	700.000	3.541.477	48.787.879	386.333	52.715.689
4.2 (Seat Bocor)	1	8	0.25	1.00	0.58	1.83	4.67	800.000	2.670.455	42.424.242	348.333	45.443.030
3.1 (Disc Korosi)	1	7	0.12	0.50	1.08	1.70	5.33	1.000.000	1.288.636	40.909.091	323.000	42.520.727
4.1 (Seat Korosi)	1	7	0.10	1.50	1.00	2.60	5.00	1.200.000	3.098.864	49.090.909	494.000	52.683.773
Total Biaya Ekspektasi Kegagalan												193.363.220

From the results obtained from Table 13, a bar chart has been made to visualize the expected failure costs per risk, which can be seen in the following Figure 3:

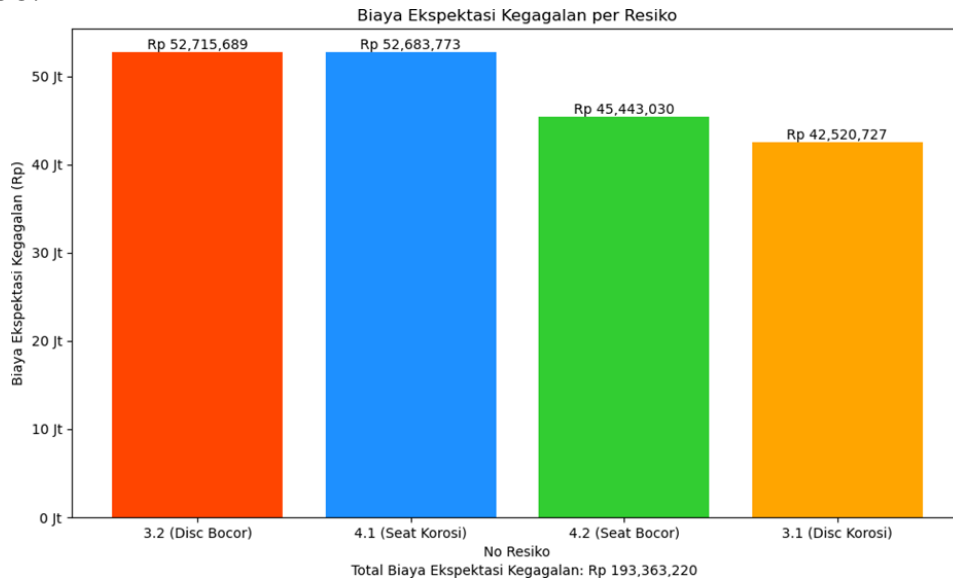


Figure 3. Bar Chart of Expected Failure Costs

From the image above, the x-axis (horizontal) is used to identify the risk number and the y-axis (vertical) to determine the expected failure cost range (Rp10-50 million). It can be observed that the highest to lowest expected failure cost is represented by the orange bar with risk number 3.2 (Disc Leaking) at an expected failure cost of Rp52,715,689, followed by the blue bar which is risk number 4.1 (Seat Corrosion) with an expected failure cost of Rp52,683,773, then the green bar which is risk number 4.2 (Seat Leaking) with an expected failure

cost of Rp45,443,030, and the lowest expected failure cost is at risk number 3.1 (Disc Corrosion) with an expected failure cost of Rp42,520,727. From each of these failure costs, the total expected failure cost amounts to Rp193,363,220.

Causes of Defects in Product Components

The fishbone diagram of cause and effect is used to identify the causes of defects in products. Below is a description of the causes of product defects:

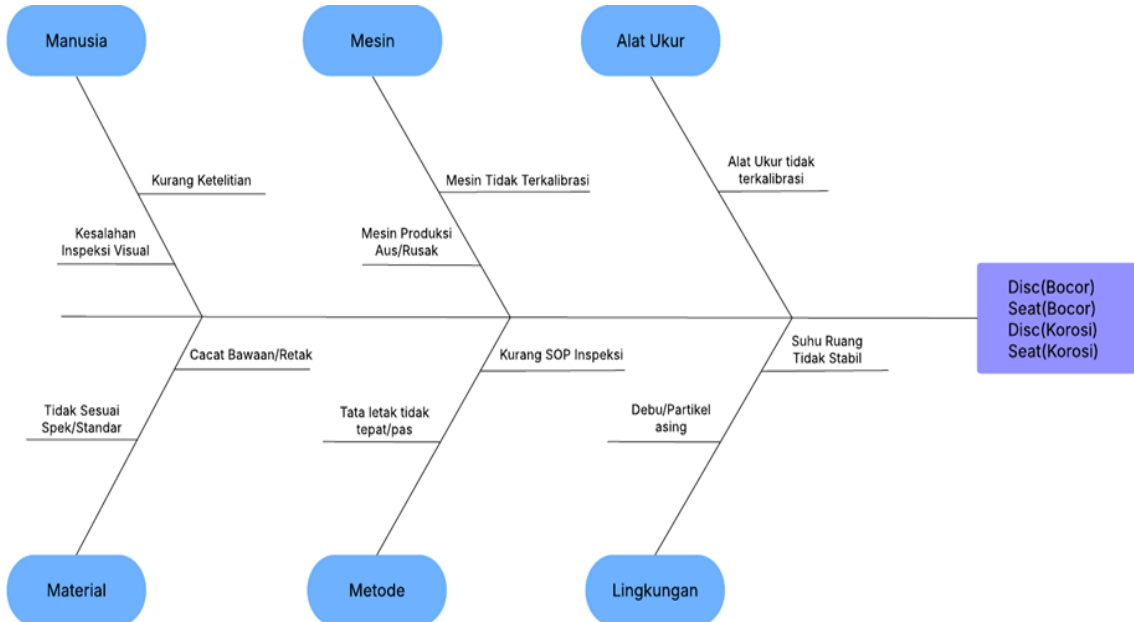


Figure 4. Fishbone Diagram on Critical Product Defects

Risk Mitigation

Resiko kegagalan produk dari tiga jenis(bocor, korosi, terkikis) kegagalan produk yang tergolong kritis di atas The first occurrence is due to materials that do not meet the specifications or standards set by the company; the second factor is human operator error, lack of meticulousness, and mistakes in visual inspection during the work process; the third factor involves machines that are no longer precise or well-calibrated, or production machines that are worn out/broken; the fourth factor is the presence of improper methods, such as insufficient inspection SOPs and inappropriate layout methods; the fifth factor is measuring tools that are not calibrated; and the sixth factor involves environmental aspects, such as unstable working room temperatures or dust/foreign particles that can cause product defects. Some solutions for improving this process include creating new specifications for the Disc and Seat that are appropriate, to ensure that all Gate Valve parts being processed are more stable. Additionally, there are times when operators are not yet proficient in operating the machines and measuring tools used. To fix this, it is necessary to test and provide training to determine whether the operator is capable of operating the machine and reading the measuring tools correctly according to the appropriate procedures. Sometimes there are measuring tools that have passed their calibration period, which causes the measuring tools to become imprecise; thus, the company is required to recalibrate those measuring tools to obtain more accurate results. Additionally, for environmental monitoring, digital

thermometers can be installed to monitor room temperature, ensuring it remains stable and that the working process is protected from foreign dust particles during production.

CONCLUSIONS AND RECOMMENDATIONS

Based on research, processing, and data analysis that has been conducted regarding the risk of quality and the expected cost of failure with FMEA cost-based on the production process of Gate Valves, several conclusions can be drawn as follows:

1. Based on the risk identification process using the FMEA method that has been conducted on the production process of Gate Valves at the company where I did my internship, it was found that there are 17 types of risks from 8 components that make up the Gate Valve that can affect production quality.
2. Based on the risk calculation results using the Risk Priority Number or RPN method, there are four major risks categorized as critical that faced failures in the Gate Valve production process. These failure risks include components such as Disc (Leak)(3), Seat (Leak)(4), Disc (Corrosion)(3), and Seat (Corrosion)(4). Based on the risk evaluation conducted through the Probability Impact Matrix or risk mapping, it was found that there are two types of risks that fall into the critical category and may cause failures in the production process, specifically in the components Disc (Leak)(3) and Seat (Leak)(4).
3. From the risk assessment results based on costs using the FMEA method, it can be concluded that failures in the Gate Valve production process over the last three months, namely September, October, and November 2024, will result in a total cost of Rp.193,363,220. This failure is due to the failure of the identified risks in the production process.
4. Important factors that cause product defects include humans, machines, and measuring tools. There are several improvement proposals, including regular training for employees, meetings aimed at job control, regular maintenance and repair of machines, and recording and documenting work results that do not meet standards. It is advised that quality control be more meticulous in carrying out work to avoid overlooking anything.

FURTHER STUDY

This research still has limitations so that further research is needed on the topic of Risk Analysis of Component Quality in the Production Process of Gate Valves Using the Failure Mode and Effect Analysis Method to perfect this research and increase insight for readers and authors.

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