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Rubber Tyred Gantry (RTG) Failure Analysis Using FMEA Method at PT. Kaltim Kariangau Terminal Balikpapan

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KEYWORDS
FMEA
RTG
Crane
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ABSTRACT – Failure Mode and Effect Analysis (FMEA) is a method designed to evaluate system designs by identifying various failure modes of a system, which consists of multiple components, and analyzing their impacts on the system's reliability. The primary goal of FMEA is to identify and address key issues at every stage of the design and production process to prevent defective products from reaching customers, thereby safeguarding the company's reputation. This study aims to identify the types of damage occurring in Kalmar-brand Rubber Tyred Gantry (RTG) equipment at PT. Kaltim Kariangau Terminal Balikpapan and analyze these failures using the FMEA method. Data collection was conducted through field observations, interviews, and documentation. The FMEA calculations also include repair recommendations for each identified failure. Based on the analysis, several failures were found to rank highest in severity for each piece of equipment. For RTG 07, the most critical failure was the "Trouble Hoist," requiring corrective actions such as repairs to the motor system, brakes, and gearbox.

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INTRODUCTION

PT. Kaltim Kariangau Terminal (PT. KKT) is a joint venture company established by the provincial government of East Kalimantan and PT. Pelabuhan Indonesia IV (Persero) to manage and provide port services at Kariangau Terminal in Balikpapan City, East Kalimantan Province [1]. Initially, PT. KKT operates a container terminal aimed at offering efficient services in terms of time and cost to support economic activities in Kalimantan, particularly in East Kalimantan Province [2].

Service quality improvement is supported by the availability of modern loading and unloading equipment, skilled human resources, and the implementation of an international standard computerized system, as the region prepares for its role as the capital city of Nusantara, the port, including KKT, is required to stay updated and conduct short-term, medium-term, and long-term needs analyses to anticipate rising consumer demand. Moreover, KKT must undertake additional preparations since it serves as the only container terminal in Balikpapan [2].

The Rubber Tyred Gantry (RTG) crane is one of the key pieces of equipment used to transfer containers between the temporary storage yard and transport trucks or vice versa. However, operational failures or breakdowns occasionally occur, disrupting loading and unloading processes at the port and reducing port productivity [3].

Although the RTG crane plays a critical role in supporting loading and unloading operations at PT. KKT, its use has been plagued by recurring technical issues. Reports from employees and trainees who conducted internships at PT. KKT revealed that the RTG crane frequently experiences significant malfunctions. Common problems include failures in the drive mechanism and damages to the control system, leading to operational delays. Consequently, more frequent repairs and maintenance are needed to ensure the RTG's optimal performance and to minimize unwanted operational disruptions.

METHOD

Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a method designed to evaluate system designs by examining various failure modes within a system's components and analyzing their effects on system reliability. FMEA is a method used to identify the causes and impacts of potential failure modes in equipment components. It provides a detailed and systematic assessment of failure levels, enabling appropriate preventive or corrective actions [4].

The primary goal of FMEA is to detect and resolve key issues in every stage of the design and production process to prevent defective products from reaching customers, thereby protecting the company's reputation. FMEA serves as a quality planning tool to identify failures or defects [5]. It involves identifying potential failures (including their likelihood, mechanisms, impacts, detection methods, and prevention strategies). The output of FMEA is an action plan aimed at eliminating or mitigating failures.

FMEA is one of the earliest systematic techniques for failure analysis. It was developed by reliability engineers in the late 1950s to identify potential issues in military systems [6]. FMEA often acts as the initial step in system reliability studies. This process reviews as many components, assemblies, and subsystems as possible to identify potential failure modes along with their causes and consequences. For each component, the failure modes and their effects on the overall system are recorded in a specific FMEA form.

Table 1. Severity Rating

Effect	Rank	Descriptions
Dangerous without warning	10	The level of seriousness of maintenance and safety operators does not comply with government regulations that are not accompanied by warnings
Dangerous with warning	9	The level of maintenance and safety operators does not comply with government regulations that are accompanied by warnings
Very High	8	Downtime more than 8 hours
High	7	Downtime between 4-8 hours
Medium	6	Downtime between 1-4 hours
Low	5	Downtime between 0.5 - 1 hour
Very low	4	Downtime between 10 - 30 minutes
Small	3	Downtime occurs up to 10 minutes
Very small	2	Process parameter variations are not within specification limits. Other process settings or controls are needed during production. There is no downtime
None	1	Process parameter variations are within specification limits. Process settings or controls can be done during routine maintenance.

Source: Situngkir, 2019 [4]

Table 2. Occurance Rating

Rating	Probability of Occurance
10	Greater than 50 per 3528 hours of use
9	35-50 per 3528 hours of use
8	31-35 per 3528 hours of use
7	26-30 per 3528 hours of use
6	21-25 per 3528 hours of use
5	15-20 per 3528 hours of use
4	11-14 per 3528 hours of use
3	5-10 per 3528 hours of use
2	Less than 5 per 3528 hours of use
1	Never at all

Source: Situngkir, 2019 [4]

Table 3. Detection Rating

Rating	Detection Design Control
10	Undetectable
9	Very low chance and very difficult to detect
8	Very low chance and difficult to detect
7	Very low chance of being detected
6	Low chance of being detected
5	Medium chance of being detected
4	Quite high chance of being detected
3	High chance of being detected
2	Very high chance of being detected
1	Definitely detectable

Source: Situngkir, 2019 [4]

a. Severity

Severity refers to the level of seriousness or the impact caused by a failure on the overall performance of a machine. It is measured on a scale from 1 to 10. The criteria for determining severity are outlined in Table 1.

b. Occurrence

Occurrence is the level of frequency of occurrence due to a certain cause on the machine. The Occurrence rating value is between 1 and 10. A value of 10 is given if the failure that occurs has a high cumulative value or occurs very often. The level of frequency of failure (occurrence) can be seen in Table 2.

c. Detection

Detection is given to the control system currently used which has the ability to detect the cause or failure mode. The detection assessment criteria can be seen in Table 3.

Types and Sources of Data

a. Primary Data

1. RTG device identification and characteristics

   This data includes information on the technical specifications of the RTG device, such as brand, model, year of manufacture, important components and description of the device's function. This data can be obtained through technical documentation. This data can also be collected through interviews with technicians or operators who have knowledge of RTG devices at PT.KKT Balikpapan, East Kalimantan. This data is presented in the form of a table that includes specific information about the RTG device. This information will help in identifying potential damage and its impact.
2. Potential damage and cause data

   This data includes a list of potential damage modes that can occur in the RTG device and the factors that contribute to the damage. Potential damage and cause data can be collected through interviews with technicians, operators, or personnel who are experienced with the RTG device. Group discussions or brainstorming sessions can also be conducted to identify potential damage and presented in the form of a table that lists potential damage and its causative factors.
3. Impact and occurrence rate data

   This data includes the impact that occurs if damage occurs to the RTG device and the occurrence rate of potential damage. This data can be collected through interviews or discussions with people involved in the operation of the RTG equipment. This data can be presented in the form of a table or matrix that lists the level of impact and the level of occurrence of potential damage. Bar graphs or diagrams can also be used to visualize the level of occurrence or impact of damage.

b. Secondary Data

1. Industry or standard data

   This data includes information on industry standards related to RTG equipment, technical specifications, repair guidelines, or operational guidelines that have been set by related organizations or institutions. Industry or standard data can be obtained through literature studies, industry publications, or access to online databases containing related information. These sources can include international standards, manufacturer guidelines, or industry research reports related to RTG equipment and can be presented in the form of direct quotes, summaries, or tables that list relevant requirements and guidelines. This presentation helps in identifying the requirements that must be met and recommended improvement steps.

Table 4. Main Components of RTG Tools

No	Component	Description
1	Frame	It is a component of the RTG framework/initial form itself.
2	Genset	consists of an engine and generator along with its supporting devices. Where the engine is the main driver that rotates the generator, while the generator is the power producer in the form of electric current from the rotation generated by the engine.
3	Air Room	as a place to place the main electrical components for the entire RTG network
4	Cabin dan Trolley	is one component. Where the cabin is where the operator moves the function of the RTG, both from the Gantry, Trolley, and Hoist. While on the trolley there are several main components in the form of a trolley motor. In the trolley there are 2 movements, where the hoist and trolley functions are placed. Which in the cabin and trolley there are trolley motors and hoist motors along with wire rolling drums. For the trolley itself, it is a forward and backward movement to place/arrange containers in a row. While the hoist movement is a movement or function to lift and lower containers
5	Sprider	is a component located under the cabin which is connected to the wire. The spider is a component for lifting/tying, gripping containers which is known in the sense of locking the container. On the spider there is a twistlock device that functions to hold the container when it is lifted.
6	Gantry	Tires, gantry motors, gantry breaks function to mobilize or move the RTG crane to the left, right, or rotate its position when crossing.

Source: Interview Data

2. Damage history data
   This data includes records or reports of previous damage that occurred to similar RTG equipment either at PT. KKT Balikpapan or similar industries. This data can provide insight into the types of damage that often occur and the corrective actions that have been taken. This data is obtained through repair records, previous damage reports, or maintenance and repair databases at PT. KKT Balikpapan. If industry failure history data is required, sources may include industry publications, research reports, or failure databases that record incidents on RTG equipment and are presented in tabular form listing failure types, causal factors, and corrective actions taken. Graphs or charts may also be used to visualize failure trends or the frequency of certain failures.
3. RTG equipment performance reporting data
   This data includes RTG equipment performance reporting reports, such as reliability reports, routine maintenance reports, or inspection reports related to RTG equipment performance. RTG equipment performance reporting data can be obtained from PT. KKT Balikpapan's internal reporting system or through access to maintenance records and RTG equipment performance reports. If available, this data can be obtained from the RTG equipment manufacturer or maintenance service provider related to the RTG equipment. This data can be presented in tabular or graphical form listing performance parameters, trends, or patterns of changes in equipment performance over time. Bar graphs or charts may also be used to visualize the frequency of inspections, reliability, or routine maintenance performed.

Data Analysis Techniques

There are several data analyses that will be carried out according to the formulation of the problem as follows:

a. Analisis Data analysis carried out to find out what types of damage to the Rubber Tyred Gantry (RTG) equipment at PT. Kaltim Kariangau Terminal is by using observation techniques.
   - Identify all important elements of the RTG equipment, including physical components, software systems, and other elements that play a role in the operation of the RTG equipment.
   - For each element, identify and record all possible failure modesterjadi

b. To apply the FMEA method in analyzing damage to the RTG equipment at PT.KKT in Balikapapan, here are the steps that can be taken:
   - For each element, identify and record all possible failure modes.
   - Determining the level of severity (Severity), namely evaluating the impact or severity of each failure mode, considering the consequences of the failure on the safety, health, environment, operations, and overall performance of the RTG equipment. Give a severity score for each failure mode.
   - Determining the level of occurrence (Occurrence), namely evaluating the possibility or level of occurrence of each failure mode. Consider previous failure history, maintenance performed, operational environment, and other factors that may affect the likelihood of a failure mode occurring. Give an occurrence score for each failure mode.

Table 5. Types of RTG 07 Equipment Damage

RTG 07	
MONTH	**TYPES OF DAMAGE**
September	Trouble Hoist Gearbox Trouble Trouble Lock Fuel Pump Trouble Joystick Trouble
October	Unable to Start Trouble Joystick Controller Unstable Enginee
November	Trouble Hoist Not Strong Enough to Lift Weights Low Power Trouble Crane Off Cannot Start
December	Trouble Lock Trouble Lock Unlock the right side of the short Trouble Can't Control On Injector Troubleshoot Dead engine Trouble Gantry Trouble Trolley Indicator Light Turns Off Cannot Spreader Can't Crane On
January	Lock light is off Trolley Drive Trouble Trouble Trolley Dead engine Cannot Trolley Forward Trouble Lock Unlock Trouble Control Off Trouble Cross
February	Trouble Spreader Twistlock Trouble Lock Trouble Bearing and fanhub Trouble Lock Unlock Engine Under Speed Cannot Hoist and Trolley Control On Left Sea Spreader Pulley Bearing Failure

Source: Primary Data

Table 6. Causes and Effects of RTG Equipment Damage

	RTG 07		
MONTH	**TYPE OF DAMAGE**	**CAUSE**	**EFFECT**
September	Trouble Hoist	Trouble Hoist	Read hoist drive
	Trouble Lock	Trouble Lock	Container hole stuck in twistlock position
	Trouble Fuel Pump	Fuel Pump Trouble	Can no longer be used
	Trouble Joystick	Joystick Trouble	Provides inappropriate voltage to PLC where it will be read "joysteak gantry error"
October	Can't Start	Can't Start	Difficult to start
	Trouble Joystick Controller	Trouble Joystick Controller	Provides inappropriate voltage to PLC where it will be read "joysteak gantry error"
	Engine Unstable	Engine Unstable	Cannot be operated
November	Trouble Hoist	Trouble Hoist	Read hoist drive
	Can't Lift Load	Can't Lift Load	Can no longer be used
	Low Power	Low Power	Cannot lift loads
	Trouble Crane Off	Trouble Crane Off	Will often control off
	Can't Start	Can't Start	Cannot be used
December	Trouble Lock	Trouble Lock	Proximity that is not reading enough
	Trouble Lock Unlock right side short	Trouble Lock Unlock right side short	Proximity that is short
	Trouble Can't Control On	Trouble Can't Control On	Safety warning will be on before being turned off by the operator
	Troubleshoot Injector	Injector Troubleshooting	Can no longer be used
	Engine Off	Engine Off	Engine in Cut Off state at Low RPM
	Trouble Gantry	Trouble Gantry	Proximity sensor location is not right or has shifted.
	Trouble Trolley	Trouble Trolley	Cables are rolled and stuck and some cables are broken.
	Indicator Light Off	Indicator Light Off	Cut off and cannot operate
	Can't Crane On	Can't Crane On	Safety warning will be on before being turned off by the operator
January	Lock Light Off	Lock Light Off	Cut off and cannot operate
	Trouble Drive Trolley	Trolley Drive Trouble	When the trolley causes Fault
	Trouble Trolley	Trouble Trolley	Cables are rolled and stuck and some cables are broken. Engine in Cut Off state at Low RPM
	Engine Off	Engine Off	Cables are rolled and stuck and some cables are broken.
	Can't Trolley Forward	Can't Trolley Forward	Short proximity
	Trouble Lock Unlock	Trouble Lock Unlock	Will often control off
	Trouble Control Off	Trouble Control Off	Causes it can't move
February	Trouble Cross	Trouble Cross	Can't lock unlock
	Trouble Spreader Twistlock	Trouble Spreader Twistlock	Container hole stuck in twistlock position
	Trouble Lock	Trouble Lock	Can't be operated
	Trouble Bearing and fanhub	Trouble Bearing and fan hub	Short proximity
	Trouble Lock Unlock	Trouble Lock Unlock	Safety warning will be on before it is turned off by the operator
	Can't Hoist and Trolley Control On	Can't Hoist and Trolley Control On	Can't be used
	Damage to the Left Spreader Pulley Bearing	Damage to the Left Spreader Pulley Bearing	Read hoist drive

Source: Interview Data

- Detection level determination, namely the evaluation of early detection capability or the level of detection capability for each failure mode. Consider existing monitoring, inspection, maintenance systems, and testing processes that can detect failure modes before they occur. Give a detection score for each failure mode.

c. Find the Risk Priority Number (RPN) value. The Risk Priority Number (RPN) is a measure of relative risk. RPN is obtained by multiplying the Severity, Occurrence and Detection ratings. RPN is determined before implementing recommendations for corrective action, and this is used to determine which part is the highest priority based on the highest RPN value [7].

$$RPN = S \times O \times D \quad (1)$$

Where S (Severity) is the severity of the damage, O (Occurance) is the frequency of the damage and D (Detection) is the level of damage detection that exists. The RPN result shows the priority level of equipment that is considered high risk, as a pointer to corrective action. There are three components that make up the RPN value.

d. Prioritize corrective action: Identify the failure modes with the highest RPN Numbers, because they represent the greatest risk. Focus corrective efforts on the failure modes with the highest RPN scores and allocate appropriate resources to reduce risk and prevent these failures from occurring.

RESULTS AND DISCUSSION

Rubber Tyred Gantry At Pt.Kaltim Kariangau Terminal

a. Main components of Rubber Tyred Gantry
The main components of the Rubber Tyred Gantry tool at PT.Kaltim Kariangau Terminal can be seen in the Table. 4.

b. Damage to Rubber Tyred Gantry 07
PT. Kaltim Kariangau Terminal has 2 (two) types of Rubber Tyred Gantry (RTG) namely RTG type ZPMC and RTG type Kalmar. Both have the same working system but different brands of unit manufacture and have differences in several component parts. For RTG Brand Zpmc initially used many card components in its electrical system because seen from the year of manufacture RTG Brand Zpmc is considered old. In RTG Brand Zpmc dominantly uses Limit Switch while for RTG Brand Kalmar uses more proximity type sensors, for the year of manufacture RTG Brand Kalmar is considered more Improved than RTG Brand Zpmc at PT. Kaltim Kariangau Terminal Balikpapan. Table 5 reveals types of RTG 07 equipment damage

c. Causes and Effects of RTG Equipment Damage
The damage to the Rubber Tyred Gantry tool that occurred at the PT.Kaltim Kariangau Terminal certainly has causes and effects of damage that are important to handle so that no further damage occurs to the same tool or to other RTGs. Table 6. Shows the causes and effects of RTG damage within a period of 6 (six) months.

d. Application of Failure Mode and Effect Analysis Method to RTG equipment damage
The intended damage frequency includes damage periods within 6 months, namely the months of September 2023 - February 2024. In determining the damage period, the author processed data on monthly equipment damage reports. Rubber Tyred Gantry (RTG) damage can be seen in Table 7.

Table 7. RTG 07 Equipment Failure with Highest Frequency

No.	FAILURE	FREQUENCY
1	Troubleshoot Injector	23.40
2	Gearbox Trouble	17.05
3	Hoist Trouble	15.32
4	Not Strong enough to lift load/Low Power	10.58
5	Bearing and fanhub Trouble	10.58
6	Fuel Pump Trouble	10.10
7	Joystick Trouble	09.56
8	Trouble Trolley	09.43
9	Left Sea Spreader Pulley Bearing Damage	07.30
10	Right Side Lock Unlock Trouble Short	06.00

Source: Secondary Data

Table 8. Severity Rating RTG 07

DAMAGE	*SEVERITY RATING*									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Injector Troubleshooting										
Gearbox Trouble										
Trouble Hoist										
Low Power										
Trouble Bearing Fanhub										
Fuel Pump Trouble										
Joystick Trouble										
Trouble Trolley										
Marine Left Spreader Pulley										
Bearing Damage										
Trouble Lock Unlock the right side of the short										

Source: Primary Data

Table 9. Occurance Rating RTG 07

DAMAGE	*OCCURANCE RATING*									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Troubleshoot Injector										
Gearbox Trouble										
Hoist Trouble										
Unable to Lift Load/Low Power										
Fanhub Bearing Trouble										
Fuel Pump Trouble										
Joystick Trouble										
Trouble Trolley										
Left Spreader Pulley										
Bearing Damage										
Right Side Lock Unlock Trouble Short										

Source: Primary Data

Table 10. Detection Rating RTG 07

DAMAGE	*DETECTION RATING*									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Troubleshoot Injector						■				
Gearbox Trouble					■					
Hoist Trouble				■						
Unable to Lift Load/Low Power			■							
Fanhub Bearing Trouble				■						
Fuel Pump Trouble				■						
Joystick Trouble				■						
Trouble Trolley			■							
Left Spreader Pulley				■						
Bearing Damage				■						
Right Side Lock Unlock Trouble Short			■							

Source: Primary Data

From the table above, it can be seen that the damage to the RTG 07 tool that has the highest frequency is the injector troubleshoot, where in a period of 6 months this damage occurs with a total frequency of 23 hours 40 minutes. This injector troubleshoot damage is usually caused by the age of the injector itself, resulting in the injector being unusable and having to be replaced.

e. Determine the level of severity, frequency of occurrence and detection

In this study, the author uses the Failure Mode and Effect Analysis method where the calculation requires the calculation of the Risk Priority Number (RPN). Before calculating the RPN for equipment damage, it is required to analyze the severity, frequency of damage and detection of the damage. Figures regarding the severity, frequency of occurrence and detection of equipment damage are obtained based on field observations and also seen from the equipment downtime. The following are calculations regarding Severity, Occurrence, and Detection for damage for each RTG.

The following is a calculation of the severity level, frequency of occurrence and damage detection on the RTG 07 tool.

- Severity
  The severity number given to each tool damage can be seen in Table 8.
- Occurrence
  Table 9 shows the occurance rating RTG 07
- Detection
  Table 10 shows the detection rating RTG 07

f. Risk priority number calculation

The Risk Priority Number (RPN) calculation is used to determine the ranking/rating of each damage that occurs. The results of the RPN calculation can be used as the main benchmark for repairs. The highest ranking indicates the priority of damage that is quite severe and must be repaired and find a way to prevent the damage from happening again [8]. The results of the RPN calculation are obtained using Formula 1.

Table 11. FMEA Calculation of RTG 07 Tool

NO	DAMAGE	CAUSE	EFFECT	S	O	D	RPN	RANK	RECOMMENDATION
1	Troubleshoot Injector	Injector age	Cannot be used anymore	8	2	6	96	2	Checking the lines, fuel and its pressure
2	Gearbox Trouble	Lack of lubrication, damaged gears, overheating and loose connections	Transmission is not smooth and makes a loud noise	8	2	5	80	4	Checking the lubrication, gears, cogs and control system
3	Hoist Trouble	There is an MCB that has trouble breaking the hoist	Reads hoist drive	7	5	4	140	1	Repairing the motor system, brakes and gearbox
4	Not Strong enough to lift load/Low Power	Forced to turn off the crane because the injector is weak	Cannot be used anymore	7	3	3	63	6	Repairing the fuel system, air filter and load
5	Bearing and fanhub Trouble	Trouble with the engine, namely the radiator fan	Radiator function is not optimal	7	2	4	56	8	Checking the lubrication, fan hub and fan alignment
6	Fuel Pump Trouble	The effect of age and weakness	Can no longer be used anymore	8	2	4	64	5	Repairing the fuel flow, pressure, filter and pump itself
7	Joystick Trouble	Damage to the problematic microswitch	Provides inappropriate voltage to the PLC which will read "joysteak gantry error"	6	4	4	96	2	Checking the connectors, cables, sensors and joystick mechanism
8	Trouble Trolley	The trolley from the slow and stop sensor often gets water in it	Cables are rolled up and stuck and some cables are broken.	7	3	3	63	6	Repairing the wheels, rails and hydraulic system
9	Left Sea Spreader Pulley Bearing Damage	Worn bearings	Bearing function is not optimal	7	2	4	56	8	Replacing the bearings and checking the pulley alignment
10	Right Side Lock Unlock Trouble Short	Usually occurs due to impact	Short proximity	7	2	3	42	10	Checking the mechanism, hydraulics, sensors and control system

Source: Primary Data

Based on Table 11, it can be seen that the damage that has the highest RPN value is the trouble hoist. Where this damage has an RPN value of 18.52%. Trouble hoist occurs because there is an MCB that has trouble breaking the hoist. This damage must be repaired to the motor, brake and gearbox systems.

CONCLUSION

Criticality related to tool damage and providing repair recommendations so that it can prevent the damage from happening again. In this study, an analysis of Rubber Tyred Gantry (RTG) tool damage has been conducted using the Failure mode and effect analysis method to determine and rank the damage. Based on the analysis carried out, there are several damages that are in the first position or rating in each tool. For RTG 07 there is Trouble Hoist damage which is in the first ranking where this damage requires repair recommendations in the form of repairs to the motor, brake and gearbox systems.

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