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Identification of Train Braking Systems using Failure Mode And Effect Analysis Method at UPT Balai Yasa Surabaya Gubeng

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Abstract. Quality control of the train braking system is a critical aspect of ensuring the safety of many train passengers. This study aims to analyze the factors that will influence the failure of the train braking system, especially the problematic braking components, to improve the quality standards of the train braking system. The Failure Mode and Effect Analysis (FMEA) method is proposed to identify potential causes of failure—train braking systems. The main components of train braking, critical systems, failure modes, and causes of failure are analyzed, and preventive measures are suggested to reduce the impact of the failure. The results showed that the highest cause of failure of 49% was the failure of the braking system components in the control valve with an RPN value of 720, which could cause the brake block to bind so that leaks could occur, and the brake system would not work.

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1 Introduction

Along with the development of the times, rail transportation is an option in great demand by the general public because prices are more affordable than the others, and the estimated travel time is relatively fast. To ensure the safety of passengers, it is necessary to control risk, one of which is by carrying out regular maintenance in terms of engines, facilities, other facilities, and infrastructure.

UPT Balai Yasa Surabaya Gubeng is a company engaged in train maintenance, repair, and modification. As one of the technical implementing units, Balai Yasa Surabaya Gubeng has the duty and function of carrying out regular maintenance. The process of maintaining the train at UPT Balai Yasa Surabaya Gubeng is carried out periodically, starting from the 2-year train maintenance (P24) and the 4-year train maintenance (P24), which must be carried out optimally, which includes checking the condition of the facilities, testing the facilities, and the feasibility of the facilities at the final stage. UPT Balai Yasa Surabaya Gubeng can carry out maintenance of trains every month by covering moderate maintenance or repairs (Middle Overhaul), which includes repainting and repair of bogies, and heavy repairs (General Overhaul) such as repair of braking systems, repair of electricity and air management and repair of facilities. Problems or disturbances to trains often occur during operational times, which cannot be tolerated by the company and can cause losses both in time and financially for the company.

Based on the data obtained during the 2022 research period, which took place at UPT Balai Yasa Surabaya Gubeng, there are problems related to quality, namely the train braking system. This problem needs to be investigated continuously and improvements to optimize the quality of train braking from the train braking installation system and braking components.

Failure Mode and Effect Analysis (FMEA) is a structured procedure to identify and prevent as many failure modes as possible. [1]. The FMEA approach is a practical risk analysis framework widely adopted in risk assessment and management with outstanding results [2]–[5]. FMEA can play a better quality control role in complex products or manufacturing systems by identifying failure modes, risk assessment, and application of industry standards [6]. FMEA is used to identify the primary sources and root causes of a quality problem. The model assesses the relationship between the failure modes identified by the FMEA method and the defects seen in production and operations [7]. Some of the main reasons why it is necessary to apply FMEA include that it is better to prevent failures than to repair failures, increase the chances of being able to detect the occurrence of a failure, identify the biggest causes of failure and eliminate them, reduce the chances of failure and build quality of products and processes [8]–[11]. Therefore, to find out the causes of failure and defects in the train braking system, an analysis is carried out using the FMEA approach.

2 Research method

The data used in this study is secondary data obtained from historical data on train mission failures in 2022 and primary data obtained through interviews and filling out FMEA worksheets from several work units and employees who work specifically in the system section—train braking.

The steps taken in the Failure Modes and Effects Analysis (FMEA) are that each potential failure mode and its root causes in a system are examined, their effects are determined, and the severity, occurrence, and detection are classified [12]. Severity rating states that the occurrence of a failure will have an impact in the form of disruption to the system as a whole. The occurrence rating states that the probability of failure is very low, and on a scale of 10, the probability of failure is very high. Detection rating: Prior to the detection rating, it is necessary to identify the control based on the process, potential failure mode, and potential cause. Control is used as a reference for detection rating. The detection function here is to see which potential failure modes can be identified before a failure occurs and whether the controls can reduce the failures. The scale used for each of these ratings is from 1 - 10, where scale 1 has the lowest value while scale 10 has the highest value. Improving the quality of the train braking system in this research uses the FMEA (Failure Mode And Effect Analysis) method [13]. Next, the value of each RPN (Risk Priority Number), a relative risk measurement, is calculated by multiplying the severity, incidence, and detection rating [14]. The RPN is determined before implementing recommended corrective actions and is used to prioritize treatment. Mathematically, the RPN value can be expressed as follows:

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

Furthermore, based on the analysis results of the developed FMEA Worksheet, corrective actions are proposed to mitigate risk failures that may occur.

3 Results and discussion

Based on historical data on damage that occurred during 2022, the train braking system has several types of failures. Table 1 shows the system failures that occurred during 2022.

Table 1. Percentage of braking system failure

| Type of Disturbance | Number of Failures | Percentage of Failures | Cumulative Percentage |
|------------------------------------|--------------------|------------------------|-----------------------|
| Control Valve / Distribution Valve | 34 | 49% | 49% |
| Bonded Block Brakes/Braking System | 18 | 26% | 75% |
| Positioning RTL Drainage Seepage | 10 | 14% | 90% |
| Brake of Water Hose | 2 | 3% | 93% |
| Main Pipe Leak | 2 | 3% | 96% |
| Braking | 1 | 1% | 97% |

| | | | |
|--|---|----|------|
| Mechanic | | | |
| Leaky Stopcock | 1 | 1% | 99% |
| The brake shoe hanger pen has come off | 1 | 1% | 100% |

Based on Table 1, the highest failure was the occurrence of disturbances in the control valve, with 34 failures. The severity, occurrence, and detection level will be assessed to calculate the RPN value of the several types of failure.

Table 2. Calculation of RPN

| Potential Failure Mode | Potential Cause of Failure | Potential Effect of Failure | S | O | D | RPN | Rank |
|------------------------|--|---|---|----|-----|-----|------|
| Braking System Failure | Control Valve / Distribution Valve | Brake Block binding/Braking system not working/Leak | 8 | 10 | 9 | 720 | 1 |
| | Brake of Water Hose | Brake Water Hose is leaking and loose | 7 | 6 | 8 | 336 | 4 |
| | The Main Pipe of the Brake Stopcock | Main Pipe Leak | 7 | 6 | 6 | 252 | 5 |
| | Braking Mechanic | Leaking stopcock | 4 | 2 | 3 | 24 | 7 |
| | The brake shoes | Train braking can not be released | 7 | 5 | 6 | 210 | 6 |
| | | The brake shoe hanger pen is loose | 4 | 1 | 2 | 8 | 8 |
| | Bonded Block Brakes/Braking System Positioning | Bump Wheel | 7 | 8 | 8 | 448 | 2 |
| RTL Drainage Seepage | Corrosion of the braking system components, especially the surface of the Brake Cylinder | 6 | 9 | 8 | 432 | 3 | |

Table 2 shows that the highest potential causes that can cause interference with the train braking system are control valve failure, brake binding, and corrosion of braking system components. Furthermore, Fishbone diagrams identify the root causes of risk events with the highest RPN values in greater depth.

Fishbone diagram is applied here as a new graphical representation method to identify, explore, and analyze the source of problems from the train braking system so that suggestions for improvements can be given [15].

1. Fishbone Diagram of Control Valve

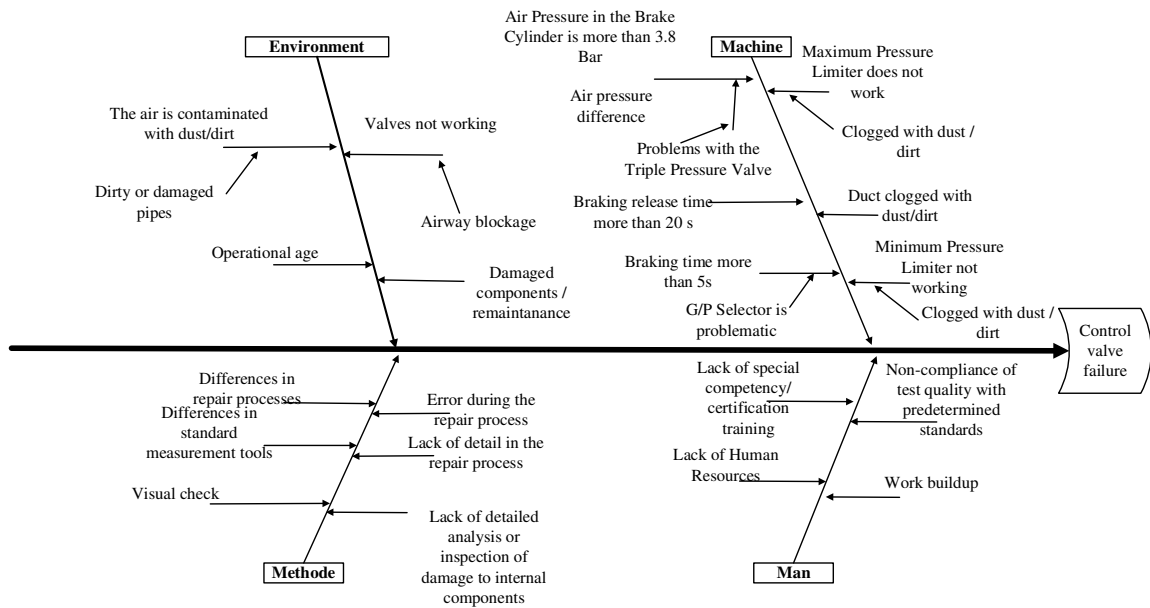


Figure 1. Fishbone diagram of control valve

The fishbone diagram above illustrates the failure of the train braking system in the control valve section, where there are four significant factors: engine, operator, or mechanic factors, repair methods used, and operational environmental factors. The fishbone diagram above shows the main critical points, namely the engine factor and the repair method factor carried

out. The engine factor refers to the valves on the control valve that are not optimal in flowing air, so there will be differences in air pressure. In contrast, for the method factor, namely where there are application repair methods that are still not optimal and by standards, especially in the testing process and maintenance.

2. Fishbone Diagram of Brake Block

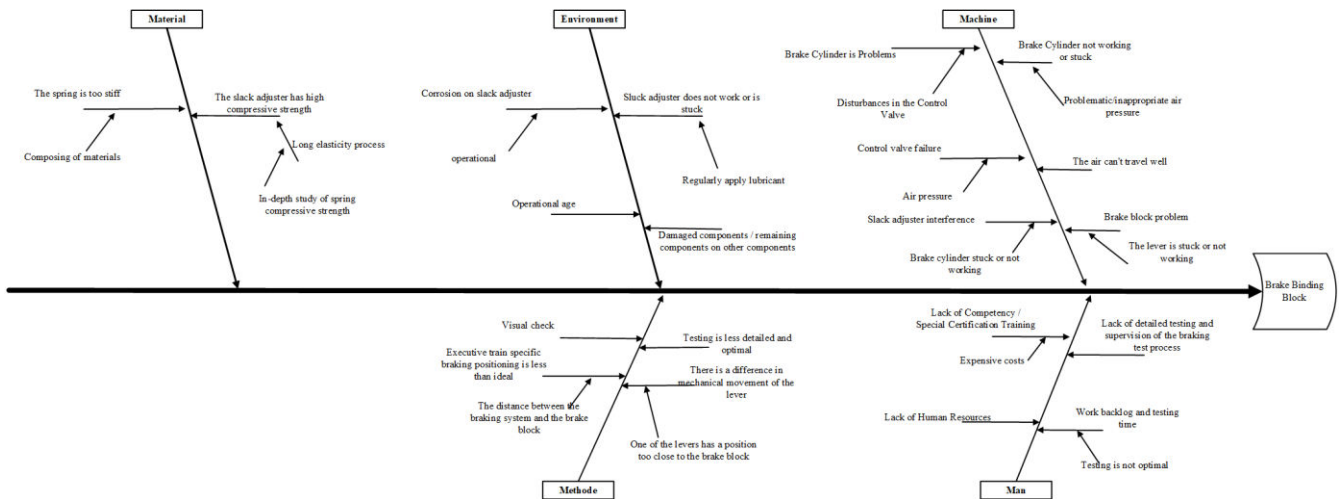


Figure 2. Fishbone diagram of brake block

The fishbone diagram above illustrates the failure of the train braking system on the brake block section, which shows five significant factors: engine, operator, or mechanic factors, repair methods used, operational environmental factors, and component building materials. The fishbone diagram above shows the main critical points, namely the engine factor, the repair operator factor, and the repair method factor carried out, where the engine factor refers to previous failures

on the control valve or cylinder brake not working. The operator factor, namely the lack of competent human resources, and the method factor, namely the maintenance and testing processes, are less detailed and specific, especially according to the manufacturer's standards that make these components.

3. Fishbone Diagram of Corrosion on Train Braking System Components

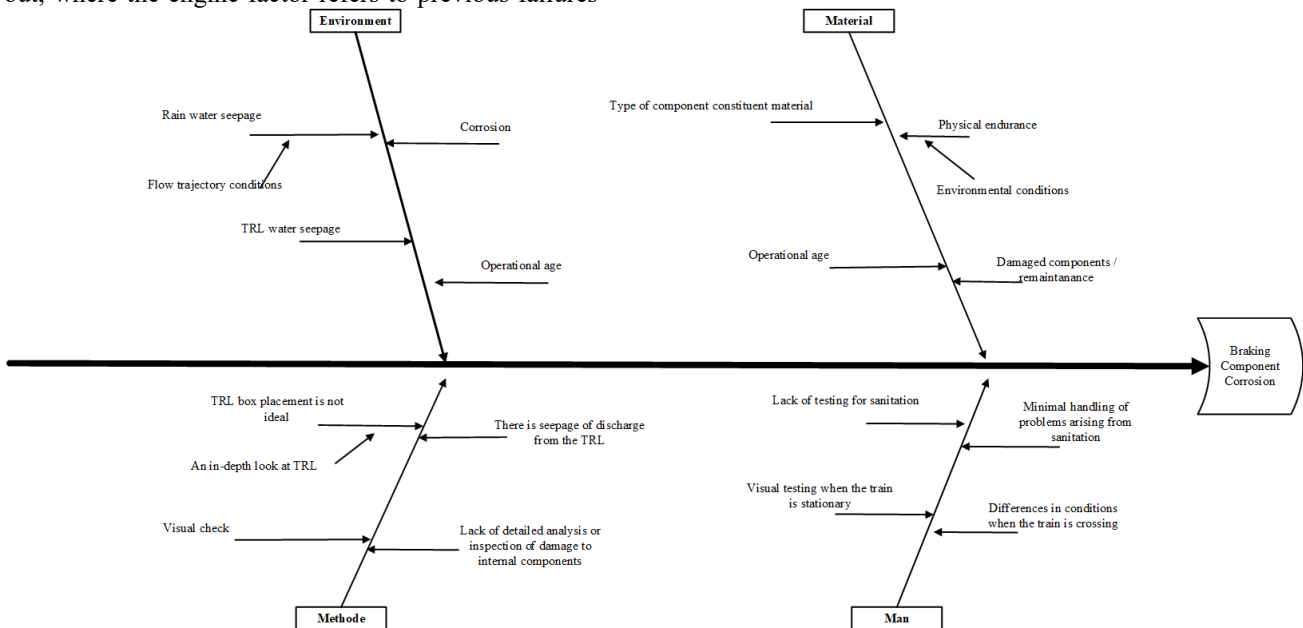


Figure 3. Fishbone diagram of corrosion on braking components

The fishbone diagram illustrates four significant factors: machine, operator or mechanic factors, repair methods used, and operational environmental factors. The fishbone diagram above shows the main critical point, namely the environmental factors during an operation where there is water seepage from the TRL disposal tank, which makes the components of the braking system, especially the cylinder brake and reservoir water tank, corrode as a result of TRL discharge water during train operation.

train braking system unit, obtained several conclusions as follows:

1. In the Failure Mode and Effect Analysis (FMEA) method, seen based on the potential cause, the selected RPN value is in the cumulative total data of 80%; there are three most significant RPN values, namely:
 - a. Failure of the braking system components in the control valve section
 - b. The occurrence of brake blocks or brake blocks that bind to the wheels
 - c. The damage to the components of the train braking system is due to

4 Conclusion

The results of observations from research conducted at UPT Balai Yasa Surabaya Gubeng, especially on the

- corrosion due to residual water from environmentally friendly toilet disposal.
2. Analysis with the help of a fishbone diagram determines the root cause of the problem based on the selected failure. There is a root cause of the failure, which is where
 - a. Failure of the control valve has two major influencing factors, operator and mechanical factors, during maintenance and repair.
 - b. The process of brake block occurrence has several factors, especially the ongoing factor of the failure of the working system on the control valve, mechanical factors in the form of an inefficient system installation process, and maintenance and repair operator factors.
 - c. The occurrence of damage to the components of the train braking system due to corrosion is caused by mechanical factors and environmental factors
 3. This study has several suggestions for improvement based on the root of the existing problems, namely:
 - a. A special work evaluation must be carried out for the operator in the braking section to be more professional and have broad insight by holding limited training within the company or training for related companies, especially in exploring the control valve field.
 - b. Applying two testing methods, namely static and dynamic
 - c. Updating test equipment or repairs with new materials according to predetermined standards
 - d. Evaluate the design of the undercarriage system with the manufacturer or designer company.

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