

Analysis of Potential Damage to Hydrotester Machines Using FMEA and FTA Methods at PT. ISP to Improve Maintenance Reliability

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Article Information	ABSTRACT
Article History Received : September 10, 2025 Revised : October 02, 2025 Published : October 10, 2025	PT. Indal Steel Pipe (ISP) is a steel pipe manufacturing company that relies on hydrotester machines as an essential tool to ensure product quality. The high production volume and intensive use of machinery have led to frequent failures, such as water hose leakage, rubber seal damage, and electrical system failure. These issues led to unplanned downtime of up to 3.09% of total operating time and 400 minutes of repairs in the last six months, which reduced productivity. This study aims to identify the hydrotester components with the highest risk of failure and establish maintenance priorities. The methods applied are Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA). FMEA is used to calculate the Risk Priority Number (RPN) based on severity, frequency, and detection, while FTA helps to systematically trace the root cause of failure. The results showed that the broken pipe rubber had an RPN value of 245, followed by a leaky hydrolis with an RPN of 180, followed by a leaking water pipe hose with an RPN value of 168. Further FTA analysis identified material wear and excessive operational stress as the dominant causes of failure. These findings highlight that combining FMEA and FTA provides an effective approach in formulating maintenance strategies, thereby minimizing risk, reducing downtime, and ensuring production continuity. The novelty of this study lies in integrating FMEA and FTA to prioritize maintenance actions specifically for hydrotester machines, offering practical guidelines for industries with similar equipment.
Keywords: <i>Hydrotester machine; Machine failure; FMEA; FTA; Maintenance.</i>	

INTRODUCTION

Product quality is a key factor in maintaining the company's competitiveness in the manufacturing industry. Quality plays a key role in influencing repeat purchase decisions in a business, making it a highly important factor in the business context (Chairunnisa & Priyandari, 2023). Good quality control not only ensures product conformity with standards, but also helps to reduce the number of failed products and improve the efficiency of the production process (M. Syahril et al., 2024; Hidayat et al., 2024). In the context of the steel industry, the quality of the pipes produced has a strategic role because it is directly related to safety, reliability, and customer satisfaction. A product can be said to be of quality if it is able to meet needs and provide added value for users. Therefore, every manufacturing company always emphasizes the importance of quality control as an effort to maintain business continuity in the midst of global industrial competition (Markatos & Mousavi, 2023; Huda et al., 2023). Quality control is an effort to maintain the quality of the goods produced so that it is in accordance with the product specifications that have been determined based on the discretion of the company's leadership

(Zadilah, 2019). Product defects have a significant impact on profit, public perception of the brand, and customer satisfaction. Company profits decline when product defects are widespread (Fauzi & Aulawi, 2016).

PT. Indal Steel Pipe, as a subsidiary of Maspion Group, is a steel pipe manufacturer located in the Maspion Unit V industrial estate, Gresik, East Java. In carrying out its operations, the company relies on various modern machines, one of which is a hydrotester, which functions as a vital tool to ensure that pipes are free from leaks and meet safety standards. To identify production processes that experience quality degradation with the FMEA method, the steps taken include tracing the factors causing the quality degradation, then assessing the severity of each cause to determine the priority of improvements that need to be made. Improvements in a company's product quality can be achieved through the implementation of appropriate quality control measures (Fahry et al., 2019). However, the results of observations show that the company still faces challenges in the form of high frequency of hydrotester machine damage. Damage that occurs, such as water hose leaks, rubber damage, and electrical system disruptions, interferes with productivity and has the potential to hinder the achievement of production targets (Sutiono et al., 2022; Putri et al., 2024). Quality is a very important indicator in the industrial world because it reflects various characteristics of products and services, including aspects of marketing, engineering, production, and maintenance (Khrisdamara, 2022).

Although FMEA has been widely used in industry to rank risks based on severity, occurrence, and detection, this method alone often provides only a quantitative assessment without explaining the logical relationship between failure events. On the other hand, FTA is effective in systematically tracing the root causes of failure but does not provide prioritization based on risk levels. Previous studies generally applied only one method, resulting in limited insights either in terms of prioritization or causal analysis. This gap underlines the need to integrate both approaches. By combining FMEA and FTA, it is possible not only to identify which hydrotester components are most vulnerable but also to understand the underlying mechanisms that trigger failures. This integrated approach is expected to provide more comprehensive and actionable recommendations for preventive maintenance compared to using FMEA or FTA alone (Novantya et al., 2025; Isrofi & Rachmaniar, 2023).

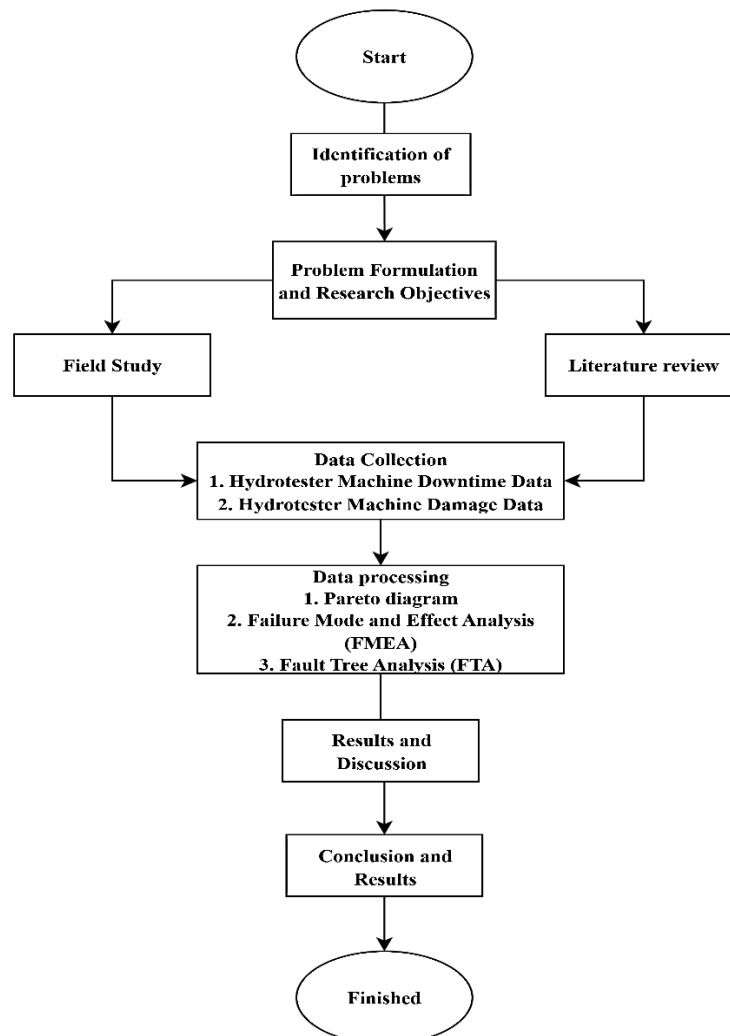
Against this background, the main purpose of this study is to find out the components of the hydrotester machine that are most at risk of damage and identify the dominant causes of the failures that occur. Therefore, this study applies the FMEA (Failure Mode and Effect Analysis) method to determine the severity, incidence, and detection, so that the RPN value is obtained (Baad et al., 2025). Furthermore, this research is also directed to provide preventive maintenance recommendations to increase the reliability of the hydrotester machine and support the smooth production process of steel pipes at PT. Indal Steel Pipe. A product is considered defective if it fails to meet specifications, has poor quality, does not satisfy customers, and may be difficult to repair into a usable product (Ardiansyah & Wahyuni, 2018).

RESEARCH METHODS

Using a case study methodology based on quantitative description, this study examines hydrotester machines in the steel pipe industry. The data used comes from engine downtime records during the period December 2024 to May 2025 as primary data. Secondary data sources were obtained from the literature and previous research related to the application of FMEA and FTA methods in engine damage analysis. The data collection process is carried out through field observations, company documentation, and interviews with maintenance technicians. The collected data was analyzed using FMEA and FTA methods to identify potential failure modes in the machine, the impact caused by failure, the root cause of the failure, and the detection mechanism that can be carried out.

Each failure mode is evaluated based on three aspects, namely severity, frequency of occurrence, and ability to detect it, so that a Risk Priority Number (RPN) value is obtained. The RPN value is used as a basis for sequencing risk priorities and formulating appropriate preventive

care measures. The analysis was continued with FTA to describe the cause-and-effect relationship of the failure that occurred, so that the dominant factors that triggered the damage to the hydrotester machine could be known. (Sembiring et al., 2018). To ensure the reliability of the findings, the results of the FMEA and FTA analysis were validated through discussions and confirmation with experienced maintenance technicians and experts at PT. Indal Steel Pipe, so that the identified risks and recommended preventive actions reflect actual operational conditions.



Picture 1. Diagram *Flowchart* Research.

a) Early identification

The researcher conducted a literature study and field observation to identify the problem of high damage to hydrotester machines, then formulated the research objectives and scope of the damage data from December 2024 to May 2025.

b) Stages of Data Collection and Processing

Primary data in the form of downtime and machine damage was collected from the production department, supported by interviews and company documents. The data was processed with a Pareto diagram, then analyzed using FMEA to calculate RPN and FTA values to trace the root cause of the main damage.

c) Outcome level and discussion

The processed data is further analyzed to find the most significant problems. The Pareto chart gives an idea of the proportion of the types of damage that occur

most frequently. FMEA is used to determine the order of priority of risks based on the RPN value, so that the engine components that need the most preventive maintenance can be identified. The analysis is followed by the FTA to explain the main causative factors of the damage, such as material wear, excessive operating pressure, or procedural errors. The results of this discussion are the basis for formulating a more effective maintenance strategy.

d) Conclusion and Suggestion Stage

The final stage of the study is to conclude the main findings based on the analysis of FMEA and FTA, namely the components of the hydrotester machine with the highest level of risk and their dominant causative factors. From these results, the researcher provided recommendations in the form of the implementation of preventive maintenance, replacement of materials with better quality, and improvement of machine operation SOPs. This suggestion is expected to reduce downtime, maintain production stability, and support the achievement of the company's targets.

The determination of severity, incidence value, and findings is based on predetermined assessment criteria. The following criteria are severity, incidence and detection value.

Table 1. Saverity Values

Hazard level	Criterion	Level
Very, very dangerous	Component damage can occur suddenly and potentially endanger work safety.	10
Very Dangerous	Damaged components can cause work accidents and make the machine malfunction, although there are still warning and early detection systems in place.	9
Very high risk	If the component fails, the machine will stop operating so that it cannot perform its main function.	8
High Risk	Component damage may cause the system to stop, but the machine can still operate.	7
Medium (Moderate) risk	Damage to components may degrade system performance, but the machine can still be used.	6
Low Risk	Component damage can gradually degrade system performance, while the machine remains operating.	5
Very Low Risk	Component damage affects the system performance slightly, so the machine remains in good working order.	4
Small Risk	The components suffered a decrease in performance, but the engine and fuel system remained in good working order.	3
Very Small Risk	The components look bad, but the components still work well, and the system and machines still run well.	2
None	No influence	1

Table 2. Occurrence Values

Rate occurs	Number of events	Level
Occurs so frequently that damage is unavoidable	It almost always happens in less than one or two surgeries.	10
Occurs very often	High occurs in less than 3 to 4 surgeries.	9
Frequent	The high occurs in less than five to eight surgeries.	8
Quite Frequent	Strong enough within 9–20 operations	7
Rare	Intermediate occurs between 21 and 80 surgeries.	6
Quite Rare	Low occurs in less than 81-400 surgeries.	5
Sometimes it happens	It is very rare in a time between 401 and 2000 surgeries.	4
Very rare	Very rarely in less than 2001 up to 15 thousand surgeries	3
Almost never happens	Hammer never performed more than 15001 operations in the same time.	2
Never happen	Never happened	1

Table 3. Nilai Detection

Detection	Criterion	Level
Impossible to detect	Will not be able to control and/or detect the source of possible failures as well as further damage	10
Very difficult to detect	Controlling change is very difficult to identify potential causes and subsequent types of failures.	9
Difficult to detect	It is difficult to manage changes so that potential causes and subsequent types of failures can be identified	8
Very low chance of detection	It is very difficult to identify the potential cause and the associated type of failure	7
Low chances of detection	It's easy to find the potential cause and the next type of failure.	6
Medium detection	The potential cause and type of failure are almost undetectable. Next	5
The chances of detection are quite high	Potential causes and subsequent types of failures are almost impossible to find.	4
Easy to detect	It's easy to identify potential causes and the next type of failure.	3
It's easy to detect	It is easy to identify potential causes and types of advanced failures.	2
Detection can be done easily/visibly	It is thought to be frequent, allowing the identification of potential causes and events	1

RESULTS AND DISCUSSION

Types of Hydrotester Machine Breakdowns

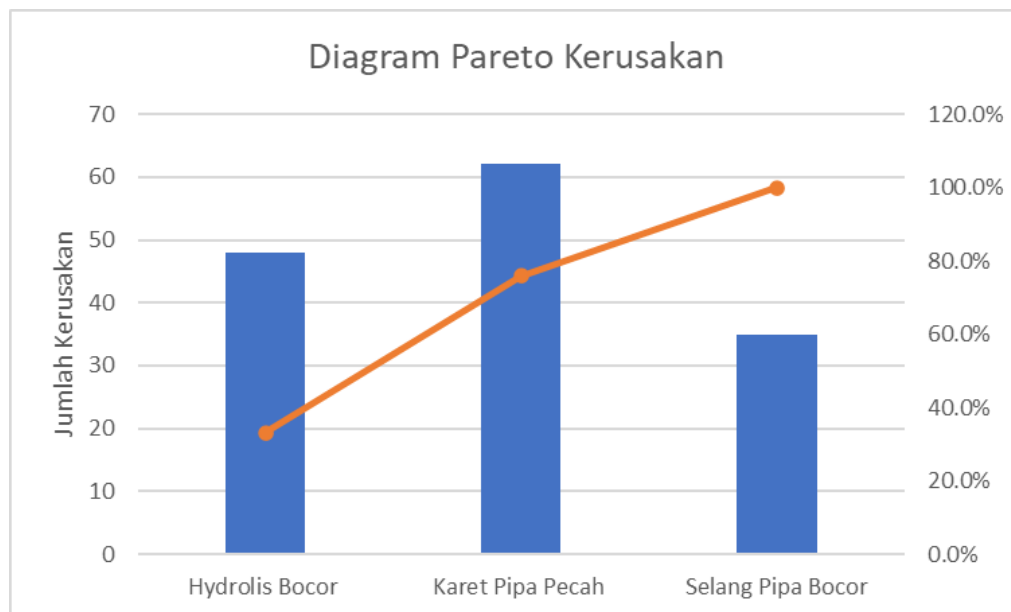
From December 2024 to May 2025, researchers collected data on the evaluation of Hydrotester engine damage and processed data on various damage to Hydrotester engine parts. Data on Hydrotester engine damage for the period of December 2024 and May 2025 is summarized below.

Table 4 . Hydrotester Machine Breakdown Data Recapitulation

No	Types of defects	Total damage	Presentase	Cumulative
1	Hydrolis Bocor	48	33.1%	33.1%
2	Rubber Pipe Burst	62	42.8%	75.9%
3	Hose Water Pipe Leaking	35	24.1%	100.0%
4	Total Disability	145	100%	

Analisa diagram Pareto

To focus efforts on fixing the problem, the Pareto chart can be used to identify the most dominant type of breakdown Based on hydrotester engine breakdown data for the period December 2024 to May 2025. (Putra et al., 2023)



Picture 2 . Diagram Pareto

It can be seen that the largest type of damage is broken rubber pipes with a total of 62 cases or about 42,8% of the total damage. Furthermore, damage in the form of leaking hydraulics occupied the second position with 48 cases or 33.1%. Meanwhile, leaking pipe hoses were recorded as many as 35 cases or 24.1%. From these results, it can be concluded that pipe rubber damage is the most dominant problem that needs to be prioritized to be handled, because it contributes the largest to the occurrence of engine downtime.

Calculation of RPN values using the FMEA method

FMEA is effective for identifying failures, prioritizing risks through RPN, and supporting mitigation in maintenance management (Antonius., 2020). RPN is a number that ranks the potential failures of a process which in itself has no inherent significance or value (Bakhtiar et al., 2016).

Table 5. RPN Hydrolis Value Assessment Leaked

Types of damage	Impact of potential damage	Potential Factors Causing Damage	S	Or	D	RPN
Hydrolis bocor	Decreased pressure that causes the engine to not work optimally to the potential for failure	Rubber sill Hydrolis break	6	5	6	180
		Over – Tightening	5	6	5	150
		Vibration and repetitive load	6	5	5	150
		Low or non-specific material quality	4	4	8	128

From the table above, it can be seen that the highest error in the Hydrotester engine experienced a broken Hydraulic sill rubber with a value of RPN 180.

Table 6. RPN Value Assessment of Leaky Pipe Rubber

Types of damage	Impact of potential damage	Potential Factors Causing Damage	S	Or	D	RPN
Rubber pipe burst	system pressure reduction so that engine performance is reduced	Too loose rubber size setting	7	7	3	147
		Less hard when connecting rubber	6	6	5	180
		Poor quality rubber	7	7	5	245
		Uneven cuts	5	5	8	200

From the table above, it can be seen that the highest error in broken pipe rubber is caused by poor quality rubber with an RPN value of 245.

Table 7. Assessment of the RPN Value of the leaking pipe hose

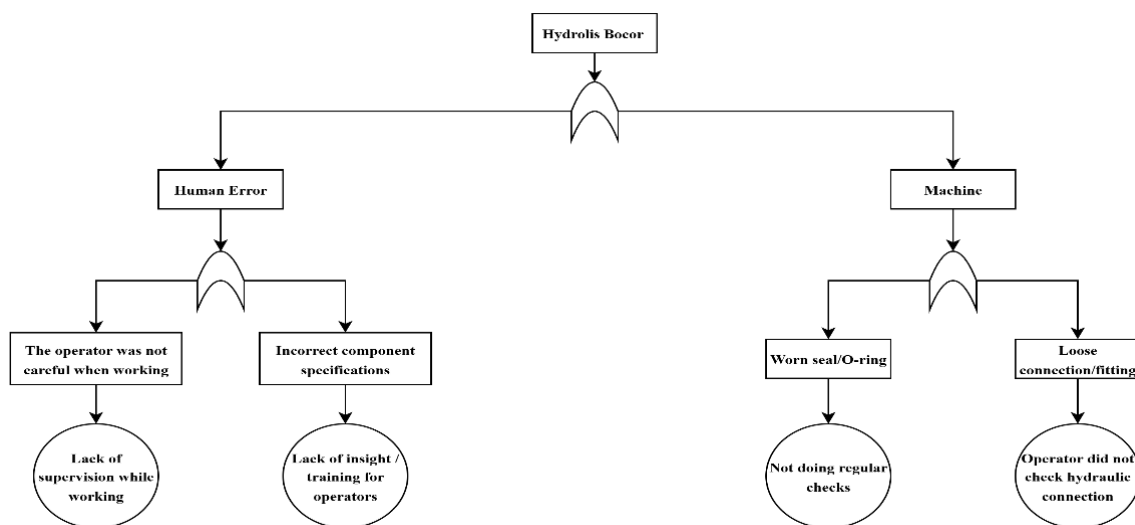
Types of failures	Impact of potential failure	Potential Factors Causing Failure	S	Or	D	RPN
Water pipe hose leaking	system pressure reduction so that engine performance is reduced	Inclusion of objects	6	2	8	96
		Over-high preassure settings	6	4	6	144
		Employees are less conscientious	5	5	6	150
		Poor quality of rubber sill	7	6	4	168

It can be seen that the highest error in the leaking pipe hose is caused by poor quality of rubber sill with a value of RPN 168. The type of reject with the highest RPN value needs to be prioritized first in its control in order to reduce potential losses due to product defects. The descriptive results indicate that the broken pipe rubber, hydraulic leaks, and water hose leakage were the most frequent and critical failures, with RPN values of 245, 180, and 168 respectively. Beyond the numerical ranking, these findings imply that the company's current preventive maintenance program has not yet sufficiently addressed the wear-prone components that directly affect machine reliability. In particular, the high RPN of the rubber seal suggests that replacement intervals may need to be shortened or material specifications reviewed. Meanwhile, recurring hydraulic leaks point to weaknesses in the inspection routines and the need for stricter monitoring of operating pressure.

From a broader perspective, the results highlight that the company's maintenance system is still largely reactive, focusing on repairs after breakdowns occur. By integrating FMEA and FTA into the maintenance framework, PT. Indal Steel Pipe can shift toward a more proactive strategy that not only prioritizes the most critical components but also addresses the root causes of failures. This shift has practical implications: reducing unplanned downtime, improving production continuity, and ultimately enhancing the competitiveness of the company's steel pipe products in the market.

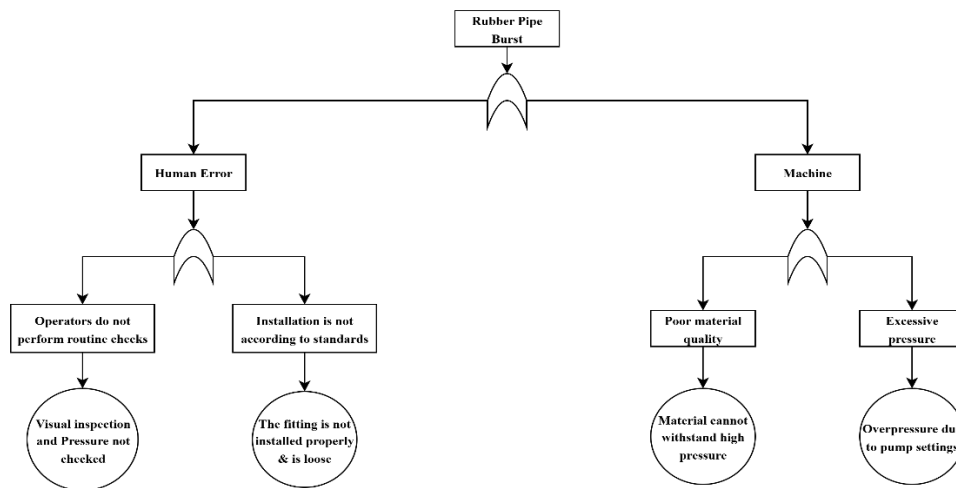
FTA Method

The next stage is to compile a Fault Tree or fault tree that describes the factors causing the defect represented through a tree diagram arranged with standard logic symbols. (Nugraha & Sari, 2019)



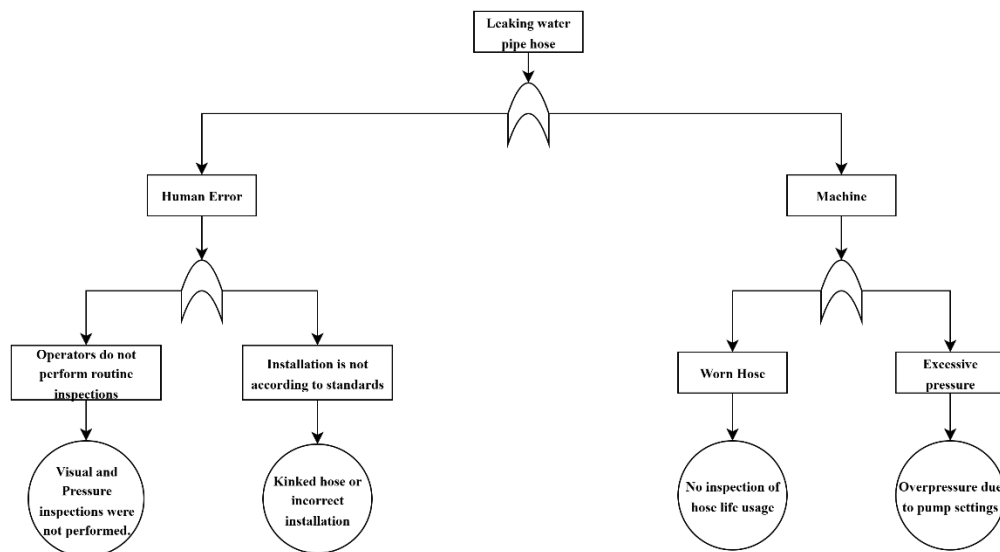
Picture 3. FTA analysis on leaky Hydrolis damage

The picture above shows the hydrolisis system that experiences problems in the form of hydrolisis leaks. This problem is caused by two main factors, namely human error and machine. Human error can occur due to operator inaccuracy when working and incorrect component specifications, which are influenced by a lack of supervision and lack of operator insight and training. Meanwhile, from the machine side, leaks are caused by worn seals or O-rings and loose joints or fittings, which arise due to the absence of periodic checks and the operator not checking the hydraulic connections. These two factors contribute to increasing the risk of leaks in the hydraulic system.



Picture 4. FTA analysis on ruptured pipe rubber damage

From the picture above, it shows that the rubber pipe system is experiencing problems in the form of broken rubber pipes. This problem is caused by two main factors, namely human error and machine. Human error can occur because the operator does not carry out regular inspections and the installation is not up to standard, for example visual and pressure inspections are not checked and the fittings are not installed neatly and tend to be loose. Meanwhile, in the machine factor, the cause comes from poor material quality and excessive pressure, such as the use of materials that cannot withstand high pressure or overpressure due to inappropriate pump settings. Both factors contribute to the increased risk of rupture of pipe rubber.



Picture 5. FTA analysis on leaking water pipe hose damage

From the picture above, it shows a problem with the Hydrotester machine which has an obstacle in the form of a leaking water pipe hose. This damage is caused by two main factors, namely human error and machine. The human error factor occurs because the operator does not carry out routine inspections and the installation of hoses is not up to standard. For example, when visual inspection of the hose and pressure conditions is not carried out, the potential for leakage is not detected early. In addition, errors in installation such as bent or loose hoses can also trigger leaks. Meanwhile, the factor from the machine side is caused by the hose being worn and excessive pressure. For example, hose material that is no longer able to withstand high pressure will easily crack or tear. In addition, inappropriate pump settings can cause overpressure, increasing the risk of leakage in the water pipe hose.

Proposed Control

At this stage, a repair plan is drawn up for each type of damage that has the potential to arise. However, in practice, PT. ISPs are advised to prioritize control on damage with the highest RPN value first. This aims to reduce the level of damage and minimize engine downtime. The following are recommended improvement proposals for PT. ISP.

Table 8. Proposed control

Types of Damage	Potential Impact Damage	Factors Causing Damage	Proposed Improvement & Control
Hydrolis Bocor	- Working pressure decreases so that test results are inaccurate	- Seal/O-ring wear due to service life	- Replace seals & O-rings regularly with a preventive maintenance schedule
	- Potential production process downtime	- Loose joints or fittings	- Use factory-standard (OEM) fittings and components
	- Risk of accidents due to slippery and flammable oil spills	- Low or non-standard component quality	- Implement daily inspections of the joint area - Create an operator daily maintenance checklist
Rubber Pipe Burst	- Pressurized water leakage interferes with the pipeline's durability test	- Rubber material does not withstand high pressure	- Use pipe rubber with specifications according to working pressure (SNI/ISO)
	- Potential engine damage due to splashing water on electrical components	- Pump pressure exceeds safe limits (overpressure)	- Set the pressure relief valve
	- Increased downtime and production losses	- Installation of non-standard pipe rubber (loose/folded)	- Train operators for standard installation - Add a visual inspection before the test starts
Water pipe hose leaking	- Fluid leakage occurs so that the test is not optimal	- Hoses wear due to service life or friction	- Replace hoses according to the service life schedule (preventive replacement)
	- Water seepage can damage floors, wiring, or surrounding equipment	- Overpressure	- Perform regular calibration of the pump so that there is no excess pressure
	- Risk of operator slipping or being exposed to pressurized water jets	- Bending hose or incorrect installation	- Apply installation standards with proper clamps - Use a hose with an additional layer of protection (reinforced hose)

CONCLUSIONS

Based on the analysis using Pareto charts, the types of malfunctions in the Hydrotester machine can be sorted from the most frequent to the rare. The most common damage was ruptured pipe rubber with a damage rate of 42.8% (62 cases), followed by leaking hydraulics at 33.1% (48

cases), and leaking water pipe hoses at 24.1% (35 cases). The results of data processing using the FMEA method show that the highest RPN value is found in the damage to broken pipe rubber, so it needs to be a top priority in control efforts. Furthermore, the analysis using FTA identified that human error, machine, and operational conditions were the main causes of the damage. Therefore, the focus of control must be directed to increasing routine inspections, selecting materials that are in accordance with standards, and controlling engine pressure so that damage can be minimized and engine downtime reduced.

As a recommendation for PT. ISPs, companies need to focus on handling damage with the highest RPN value, namely broken pipe rubber, because it has a big impact on the performance of the Hydrotester machine. This effort is important to minimize downtime, reduce potential losses, and maintain smooth operational processes. For further research development, it is recommended to use other analysis methods such as RCM (Reliability Centered Maintenance) or RAM (Reliability, Availability, Maintainability) so that the results of the evaluation are more comprehensive and the understanding of the cause of the damage can be improved.

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