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ANALYSIS OF DAMAGE TO RDT POWERROC T50 USING FOULT TREE ANALYSIS (FTA) METHOD

Darsini1[1]*, Edi Suratno[2]
Industrial Engineering Study Program, Faculty of Engineering, Universitas Veteran Bangun Nusantara Sukoharjo,Jl. Letjend Sujono Humardani No. 01 Jombor Sukoharjo 57521[12]
Email: darsini.ti@gmail.com,; edisuratno@gmail.com

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*Corresponding Author

ABSTRACT
RDT (Rock Drill Tools) Powerroc T50 is a heavy equipment widely used in the mining industry for drilling operations. Damage to this tool reduces productivity and increases maintenance costs, making a systematic analysis essential to pinpoint root causes and devise preventive measures. This study employs the Fault Tree Analysis (FTA) method to evaluate damage in the RDT Powerroc T50. The FTA facilitates hierarchical mapping of cause-effect relationships leading to system failure. Data were gathered through direct observation, technician interviews, and review of maintenance reports and damage records. The analysis reveals 14 distinct causes for damage in the rod drill section and 7 causes in the shank adapter. Common forms of damage—fractures, wear, and cracks—are largely attributed to factors such as tool fatigue and inadequate monitoring of the machine's life limit during maintenance. Insights from the FTA- based approach provide a systematic framework for identifying damage origins and implementing targeted mitigation strategies, thereby enhancing tool performance, reducing downtime, and lowering long-term maintenance expenses.

Keywords:*Fault, RDT Powerroc T50, Fault Tree Analysis (FTA), Maintenance*

1. Introduction

Mining companies often face a number of problems that can have a significant impact on business operations and sustainability. One of the mining companies operating in East Java is PT Bumi Suksesindo. PT Bumi Suksesindo (BSI) is a company that carries out gold and copper mining development activities, located in Dusun Pancer, Sumberagung Village, Pesanggaran District, Banyuwangi Regency, East Java.

One of the problems that often arise in PT Bumi Suksesindo is environmental problems, where mining activities can cause damage to the surrounding natural ecosystem. Health problems are also a serious issue in mining companies[1]. In addition, harsh working conditions and the risk of accidents in the mining workplace are also major concerns in maintaining the welfare of workers. Miners often have to work in harsh and dangerous environmental conditions, which can have a negative impact on motivation and productivity.[2]. This can affect the process of achieving goals. Human resources are needed to support efforts to achieve goals set by an organization. Guarantees of increased production and productivity are more determined by human resources who manage, control, and utilize non-human resources owned.[3]. As a result, the issue of employee safety, health, and welfare is one that must be addressed by the company. According to Government

Regulation Number 55 of 2010 concerning Guidance and Supervision of the Implementation of Mineral and Coal Mining Business, mining business activities can be temporarily stopped if they are considered to endanger the safety of mining workers/laborers, public safety, or cause losses. pollution and/or environmental damage[4].

PT Bumi Suksesindo has a Tujuh Bukit project operation which is a project in the mining sector. During the mining process, the company realized that the risk of work accidents is very high. Incidents that occur unexpectedly during mining activities, such as equipment damage due to lack of maintenance or damage analysis, lack of employee awareness of PPE (Personal Protective Equipment), and lack of attention to the importance of signs in the mining area are one of the materials for evaluating occupational safety and health in minimizing mining accidents involving employees.[5]. Based on data at the end of the quarter, Operation Tujuh Bukit achieved 13,203,098 man-hours without Lost Time Injury (LTI), while the total recorded injury frequency rate per million man-hours was 0.51 at the end of Sept 2022, with 1 recorded injury (Restricted Work Injury) during the quarter where the case of a work accident, the victim was unable to work normally in his section or was assigned to work in another type of work on the next shift/day after the accident.

Seeing the problems that are currently occurring at PT Bumi Suksesindo, management must first understand the various sources of accidents related to Occupational Safety and Health management. Accidents that often occur in mining include human factors, equipment factors, and environmental factors.[5]. Human resources are not free from errors, such as carelessness, carelessness, lack of concentration, fatigue, lack of discipline, and a sense of responsibility that results in products that do not meet company standards.[6]. Moreover, if the work involves machines, where the machine can affect product damage if it is in an abnormal condition. So quality control is needed to maintain production quality and increase marketing.[7].

Based on the urgency above, it is necessary to conduct damage analysis on mining equipment elements, namely the Rock Drill Tools mining machine using the Fault Tree Analysis (FTA) method. Damage analysis of the RDT POWERROC T50 with the application of Fault Tree Analysis (FTA) can provide insight into the possible causes of damage and its impact on equipment performance. The initial step in this analysis is that a top event is determined as the main damage to the RDT POWERROC T50. Then through the identification of potential causes, FTA forms a failure tree that details the factors that can cause the damage. Furthermore, each element is associated with a risk factor. FTA provides a comprehensive picture of the relationship between causal factors and major damage. This allows the identification of focal points for prevention and repair[8]. This analysis can also be used to measure the probability of failure at each level of the fault tree, providing quantitative information on the risks associated with a POWERROC T50 RDT failure. The use of FTA can help companies take preventive actions to mitigate potential failures, improve equipment reliability, and extend its operational life.

2. Literature Review

Definition of Quality Control

The importance of quality in company development cannot be underestimated. Currently, most consumers are starting to prioritize quality in choosing a product or service. In addition, quality is often used as a form of promotion, increasing the selling value of a company's products. As a result, currently one of the strategies used to win the competition among the many similar products on the market is to improve quality. Susetyo defines quality as "the overall characteristics of a product or service that is able to provide customer satisfaction". Meanwhile, quality according to Henndy Tannady can be interpreted as a producer's effort to meet customer satisfaction by providing what is needed, even expected from customers, where these efforts are visible and measurable from the final results of the products produced[9].

Based on the above understanding, it can be concluded that quality control is a technique or activity that aims to create, improve and maintain the quality of a manufactured product/service so that it can compete with other competitors in terms of satisfying consumers. According to Garvin (2008) in his researchNugraha and Sari (2019), there are 8 dimensions to determine the dimensions of product quality, these 8 dimensions include:

a. *Performance*is the relationship between the functional aspects of a product.
b. *Features*describes the useful aspects of performance and development of a product.
c. *Reliability*is something related to the probability of the usefulness of a product,
d. *Conformity*is the level of conformity based on consumer desires;
e. *Durability*describes the economic life of a product.
f. *Serviceability*are characteristics that include competence, speed, accuracy, and ease in providing appropriate repairs to a product.
g. Aesthetics is a subjective characteristic that is related to personal considerations and a reflection of an individual's preferences.
h. *Perceived*namely concerning the image and reputation of the product and the company's responsibility towards it.

The purpose of quality control is to ensure that the output meets the established quality standards. Here is another explanation of the purpose of quality control.[10]:

a. So that the products produced can achieve the established quality standards.
b. Try to keep inspection costs as low as possible.
c. Trying to keep the design costs of a product and process using a certain production quality as small as possible.
d. Trying to keep production costs as small as possible.

The benefits or advantages of implementing quality control for companies are:[11].

To improve quality or reduce costs.

a. Maintaining better quality overall
b. More efficient use of production tools.
c. Reduce rework and waste.
d. Better inspection.
e. Improving producer-consumer relations.
f. Better specs.

***Fault Tree Analysis*as Damage Analysis**

Fault *Tree Analysis (FTA)*is a technique for identifying system failures. FTA is function-oriented, also known as the "top-down approach", because the analysis begins at the top of the system and works its way down, or a technique for connecting a series of events that result in other events. This method uses a deductive approach to determine the cause of an event. This method is used to look into the existing problem, so Fault Tree Analysis is an analytical tool that can graphically represent the combination of errors that cause a system failure. This technique is useful for describing and evaluating system events. FTA uses two main symbols: events and gates. The following are three types of events in FTA, namely[12].

a. *Primary event*
   *Primary event*is a stage in the process of using a product that may fail. For example, when inserting a key into a lock, the key may fail to fit the lock. Primary events are further divided into three categories:
   1) Basic events
   2) Undeveloped events
   3) External events
b. *Intermediate event*
   *Intermediate event*is the result of a combination of faults, some of which may be primary events. Intermediate events are placed in the middle of a fault tree.
c. *Expanded Event*
   *Expanded Event*requires a separate fault tree due to its complexity. For this new fault tree, the expanded event is an undesired event and is placed at the top of the fault tree.

There are five stages to carry out analysis using Fault Tree Analysis (FTA), namely as follows:[13]:

a. Define the problem and boundary conditions of a system under review.
   The first step aims to find the top event which is the definition of a system failure, determined first in determining an FTA graphical model.

b. Graphical representation of the Fault Tree model

The second stage is to create a graphical model of the Fault Tree. The rules for creating FTA are:

1) Describes fault events (failure events)
2) Evaluating fault events
3) Complete all logical gates

The FTA graphical model contains several symbols, namely event symbols, gate symbols and transfer symbols. Event symbols are symbols that contain events in the system that can be depicted in the form of circles, squares and others, which have their respective meanings. Examples of event symbols are intermediate events and basic events. As for the gate symbol, it states the relationship between input events that lead to output events. The relationship starts from the top event to the most basic event. Examples of gate symbols are AND and OR

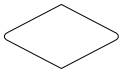
c. Finding the minimum cut set from Fault Tree analysis

The third stage is to find the minimal cut set. Finding the minimal cut set is a qualitative analysis which uses Boolean Algebra. Boolean Algebra is an algebra that can be used to simplify or describe complicated and complex logic circuits into simpler circuits.

d. Performing qualitative analysis of Fault Tree

The following are the FTA symbols that will be shown in Table 2.1 below:

Table 1. Symbols in Fault Tree Analysis (FTA)

Symbol	Information
	*Top Event*
	*Logic : Event OR*
	*Logic : Event AND*
	*Transferred Event*
	*Undeveloped Event*
	*Basic Event*

Information :

a. Top events, Undesirable events at the "top" will be further investigated towards other basic events using logic gates to determine the cause and frequency.

b. Logic gate, The logical relationship between inputs (events below). This logical relationship is expressed by an AND gate (and) or an OR gate (or).

c. Transferred event, The triangle used for transfer. This symbol indicates that the further description of the event is on another page.

d. Undeveloped event, Basic events that will not be developed further because information is already available.

*e. Basic event, k*an unexpected event that is considered

3. Research Methods

The research was conducted at PT Bumi Suksesindo. This company is located in Dusun Pancer, Sumberagung Village, Pesanggaran District, Banyuwangi Regency, East Java. Data collection techniques used interviews, documentation, and the author's personal experience.

The following is a picture of the research framework:

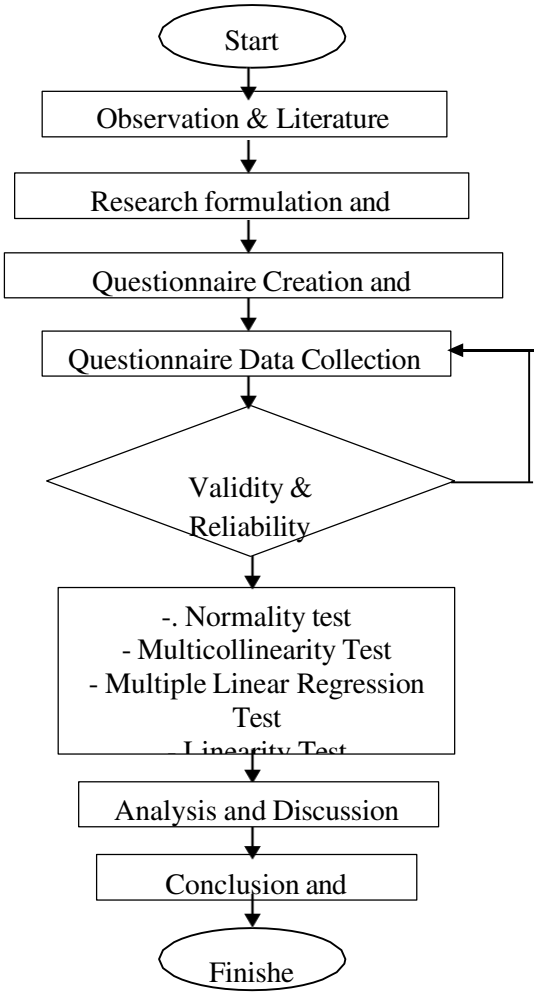


Figure 1. Research Flow Framework

4. Results and Discussion

The tool used for drilling activities at PT Bumi Suksesindo is PowerROC T50. PowerROC T50 is developed and designed for limestone and aggregate applications in the mining sector. The use of PowerROC T50 provides a high level of penetration which results in high efficiency and productivity.[14]. The drilling method used is the rotary-percussive top hammer method. The drilling tool used for drilling activities can be seen in Figure 2, while the specifications of the Technical Data and Dimensions of the PowerROC T50 can be seen in Table 2 and Table 3.

Figure 2. PowerROC T50 COP 3060 Drilling Tool

Table 2. PowerROC T50 Technical Data

Technical Data	Information
Main application areas	Mining Excavation
Drilling method	Tophammer
Hole diameter	102mm - 152mm
Product Family	*PowerROC*
Cabin	Yes
Rock Drill / DTH hammer size	COP 3060
Maximum hole depth	35 m
Machine	261 kW
Air capacity (FAD)	232 l/sec

Table 3. PowerROC T50 Dimension Data

Dimension Data	Size
Tall	3 485 mm
Long	10 900 mm
Wide	2 500 mm
Heavy	23,900 kg

The steps in creating a Fault Tree Analysis are to identify the potential causes of damage that occur in each part to be studied, then perform a detailed breakdown of the branches that form the fault tree, until the most basic event is found.Based on the data obtained at PT Bumi Suksesindo, there are damage results to the machine, namely in the Rod Drill and Shank Adapter sections. Fault Tree Analysis Analysis of broken Rod Drill damage is presented in Figure 3.

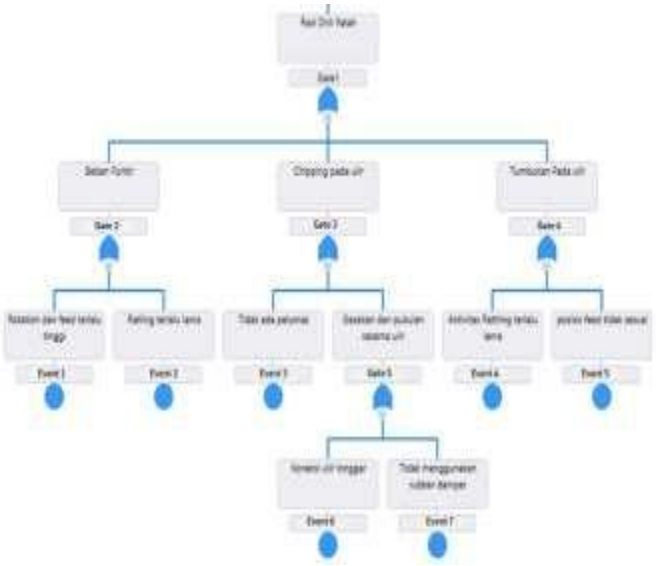


Figure 3. Fault Tree Analysis of Broken Drill Rod

From the fault tree of Rod Drill defects in Figure 3, it can be concluded that the basic events that cause defects in the form of broken rod drills include rotation and feed that are too high and rattling for too long, resulting in torsional loads, and no lubricant. Loose thread connections and not using rubber dampers result in chipping on the threads. Collisions between threads are caused by too long rattling activity and inappropriate feed positions. Fault Tree Analysis Analysis of cracked and worn Rod Drill damage is presented in Figure 4.

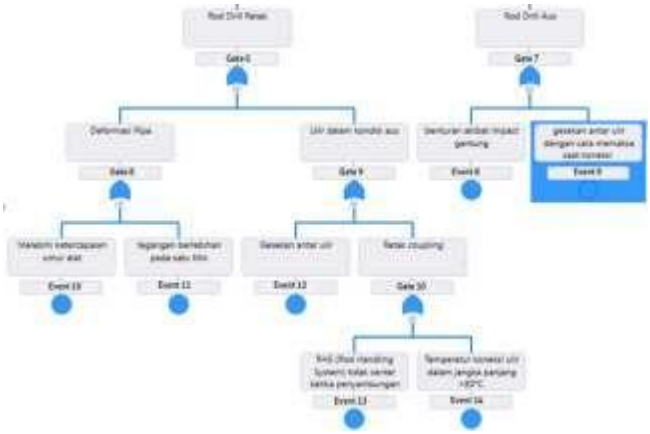


Figure 4. Fault Tree Analysis of Cracked and Worn Drill Rod

From the fault tree regarding the damage in the form of cracks on the drill rod in Figure 4, it can be concluded that the basic events that cause the damage include exceeding the tool's life span, excessive stress at one point, friction between threads, RHS (Rod Handling System) not centered when connecting, and the temperature of the thread connection in the long term >80°C. While wear damage to the drill rod, the basic event is impact due to hanging impact and thread friction due to forcing during connection.

In addition to damage to the Rod Drill, damage also occurred to the Shank Adapter. Fault Tree Analysis Analysis of the damage to the Shank Adapter worn and broken, is presented in Figure 5.

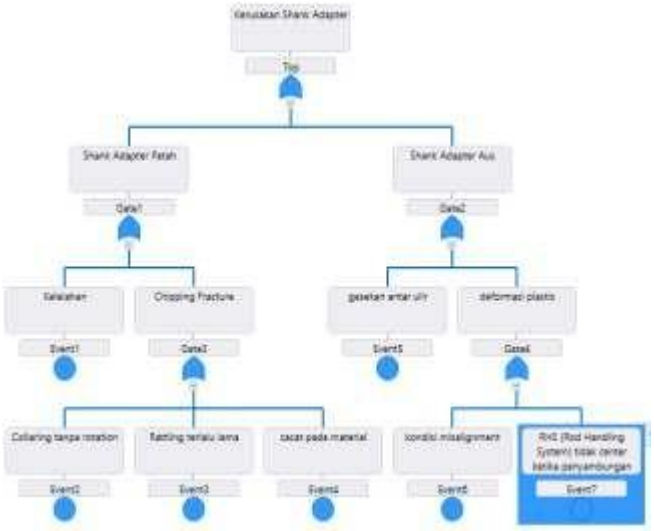


Figure 5. Fault Tree Analysis Shank Adapter Worn and broken

From the fault tree regarding the damage in the form of a fracture on the shank adapter in Figure 5, it can be concluded that the basic events that cause the damage include fatigue, material, collaring without using rotation, rattling for too long and there are defects in the material. While wear damage on the shank adapter, the basic event is thread friction due to force during connection and RHS misalignment when connecting the shank adapter to the drill rod.

From the fault tree chart of each defect that has been made, then the minimum cut set is sought to find out the root cause of the defect of the rod drill part. Finding the minimum cut set is a qualitative analysis which uses Boolean Algebra. Boolean Algebra is an algebra that can be used to simplify or describe complicated and complex logic circuits into simpler logic circuits.[15].

From the Fault Tree Analysis (FTA) method used, the factors causing defects in several parts in the rock drill tools were obtained. In addition, the main cause of defects in several parts in the rock drill can also be identified, so that more focused repairs can be made on the things that cause the most basic damage in the mining drilling machine.

5. Conclusion

Damage analysis on rock drill tools at PT. Bumi Suksesindo using the FTA method helps analyze the cause of the problem to the root of the problem. The study focused on the analysis of damage to the rod drill and shank adapter. Damage to the rod drill has 14 types of causes of damage, while the shank adapter has 7 causes of damage with an average of damage in the form of fractures, wear and cracks. Some triggers for damage to the rod drill and shank adapter are tool fatigue, operating systems that do not comply with established standards and machine maintenance in checking the machine's endurance life limit. Suggestions for PT. Bumi Suksesindo, to carry outpriority improvements for types of accidents due to equipment wear so that the resulting impact can be minimized and not detrimental to the company.

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