Performance assessment analysis of UHF machines using Reliability, Availability, Maintainability and Safety (RAMS) analysis methods

F Nurrahman* and F T D Atmaji
Telkom University, Bandung, Indonesia

*faizinurrahman.student.telkomuniversity.ac.id

Abstract. XYZ Company is manufacturing engaged in the rubber industry located in the city of Bandung, because economic growth and demand from consumers are increasing, making companies demanded to meet the target orders promptly. One way to minimize losses and the possibilities that must be borne by the company is to increase Reliability, Availability, Maintainability of the production and the safety value. Data in the form of Mean Downtime, Mean Time to Failure, Mean Time to Repair is useful for system performance that works. MTTF data can be used to assess safety systems found in PT XYZ with the safety standards of IEC 61508 using Safety Integrity Level. From the results of processing RAMS data using Reliability Block Diagram modeling based on the analytical approach, for 120 hours, the system has a Reliability value (91.12%). The average value of system Maintainability at t = 2 hours is 100%. The Inherent Availability value is 99,981% and the Operational Availability value is 99,980%. Based on the world-class maintenance Key Performance Indicator, leading and lagging availability indicators have reached the indicator target standard. Safety Integrity Level values from calculations based on PFD and RRF values of each system are in SIL 1.

1. Introduction
Machine management in the factory is one important aspect of maintaining good machine performance so that the production process continues to run well and does not harm the company. Machine management activities that can be done is to know the reliability, availability, maintainability and safety aspects of the machine. From the four aspects above, the company can measure the level of reliability of the machine in carrying out its functions, find out the availability of the machine, find out how long it will take to repair the machine, and the last to know the level of security of the machine itself.

The purpose of engine management is to determine the ability of the engine in terms of reliability, availability, maintenance, and safety level of the machine so that it is in the best performance. Several studies have been carried out regarding machine management as follows.

Rausand and Utne [1], This approach is based on a new life cycle model for product development and integrates this model into the IEC 61508 safety life cycle. High integrity pressure protection systems for offshore oil and gas applications are used to illustrate the safety approach.

Rahmawati et al. [2], This study aims to anticipate failures caused in the production process, it is necessary to evaluate the reliability and safety of each component in the separator level control system. From the evaluation results can be done recommendations in the form of rescheduling preventive maintenance of each component, reducing the value of PFD that has been installed because by lowering
the PFD value of the plant is able to maintain safety of the separator level control system, and details of the costs borne by the company when doing preventive maintenance.

PT XYZ is a manufacturing company engaged in processed rubber which is used for the automotive industry, wastewater treatment, Pertamina and similar industries. PT XYZ produces 4 types of products namely door seals, high-pressure tubes, sponge rubber, water & fuel tubes and so on. PT XYZ has four types of machines to support high-pressure tube production lines, the functions of each machine are different. Each machine on the production line has a very important role to pay attention to, because if one machine is damaged suddenly it will hamper the production process and cause the amount of production to decline and can harm the company, for example, the value of reliability and maintainability of the machine is known so that the company can reduce the level of damage by making appropriate repairs and maintenance.

In Figure 1 above it can be seen that from the four machines that produce high-pressure tubes that the UHF engine has the highest downtime frequency compared to the other three machines in two years of use. Because of the large number of requests from customers who have become partners with PT XYZ, machines that produce at PT XYZ are required to work reliably and optimally so that production targets can be met.

2. Literature review

2.1. Maintenance management
Maintenance is the activity of a damaged component or system that will be repaired under certain conditions and at certain periods [3]. The main purpose of maintenance activities is not just to optimize availability at minimum costs.

2.2. Preventive maintenance
Preventive Maintenance is a scheduled action that aims to maintain the system at a certain level by providing a systematic review, detection and or prevention of impending failure [4]. Imperfective preventive maintenance is taken when the age of the equipment reaches the controlled limit [5]. The objectives of preventive maintenance are:
- Prevent or minimize failure.
- Detect if the failure occurs.
- Finding hidden failures.
- Increase the reliability and availability of the component or system.

2.3. Corrective maintenance
Corrective maintenance is maintenance activities carried out after damage or failure of a system to return the system to its original function. This activity is unscheduled, which means it depends on the condition of the system [4].

2.4. MTTF
MTTF (Mean Time to Failure) is the average of the time interval between damage to the first component with subsequent damage with the following formulation [5]:

$$MTTF = \frac{\sum_{i=1}^{n} TTF}{n} \quad (1)$$

2.5. RAM analysis
Reliability, Availability & Maintainability (RAM) Analysis is a method that can be used to predict the performance of reliability, availability, the ability to maintain (maintainability) of a component or system. RAM Analysis is also a tool that can be used to guide the optimization of a component or system.

2.5.1. Reliability.
Reliability is a component characteristic, which is stated in the probability that it is carried out in accordance with the terms of the function under certain conditions within a predetermined time interval.

The value of Reliability on components and systems are usually expressed in terms of opportunities, with a value of R (Reliability) between 0—1.

2.5.2. Availability.
Availability is the time of a fraction of components or systems that are available for use, which means they are not closed due to failure [6]. In this Availability, there are two types, namely Inherent Availability, and Operational Availability.

2.5.3. Maintainability.
Maintainability is a characteristic of a component, which is stated by the probability that preventive maintenance or repair of the component will be carried out at the time the condition or condition is stated with time intervals for the given procedure and resources (level of personnel skills, reserve components, etc.) [7].

2.6. Safety integrity level
SIL is the security level of an instrument component that is configured with a Safety Instrumented System (SIS) [8] based on the IEC 61508 safety standard. The value of SIL can be determined through the range of PFD values.

| Safety Integrity Level | Probability of Failure on Demand | Risk Reduction Factor |
|------------------------|----------------------------------|----------------------|
| 4                      | < 0.0001                         | >10000               |
| 3                      | 0.001-0.0001                     | 1000-10000           |
| 2                      | 0.01-0.001                       | 100-1000             |
| 1                      | 0.1-0.01                         | 10-100               |

3. Result and discussion
3.1. Conceptual model
The concept in this study begins by determining the critical subsystem of the results of the Risk Matrix, after the critical components are known, can perform life data analysis using the Anderson-Darling Test on the Existing Time Maintenance data, which includes time to repair, time to failure, and downtime.

After obtaining the best distribution to represent the failure, repair, and down of each subsystem, plotting data can be done to determine the distribution parameters selected using Minitab software. The
results obtained are MTTF, MTTR, and MDT values used in RAMS Analysis. Calculation of value from RAM Analysis analytically can be done by using the distribution parameter values of each subsystem and RBD modeling to facilitate the calculation of the system RAMS.

The results of the RAM Analysis calculation are analytical RAM, namely Analytical Inherent Availability and Operational Availability. MTTF from each subsystem is used to determine the value of engine reliability, and MTTR is used to determine machine maintainability. MTTF and MTTR are needed for inherent availability calculations.

MTTF value is also used to calculate Safety Integrity Level by finding the respective sub-system lambda, then determining the PFD value and RRF value for each subsystem which later the system will be included at the SIL level according to the calculation results obtained.

3.2. Reliability block diagram

![Reliability block diagram](image)

**Figure 2.** Reliability block diagram.

In figure 4, modeling the system is done in a series manner, if one of the systems is damaged then it causes the machine cannot be used and will disrupt the production process.

3.3. Analysis of reliability

![Graphic reliability calculation results](image)

**Figure 3.** Graphic reliability calculation results.

Calculation of reliability with an analytical approach is a calculation of reliability performed using RBD on a condition of a system with the frozen state, that is, with blocks that are known to be characteristic of damage (distribution and selected parameters of subsystems) only, with the time allotted based on constant time. The steps taken in this calculation are the formulation of the system model and the calculation of reliability based on the formulation that has been done before. In figure 5 we can see the specified time is between 8 hours to 120 hours or one week, with 8-hour intervals.
3.4. Analysis of maintainability

![Figure 4. Graphic maintainability calculation results](image)

Maintainability calculation of each piece of equipment in the critical subsystem is done by using Time to Repair data that can present how much chance to improve each critical subsystem equipment. In this study, the time period that will be used as the calculation time is 15 minutes to 2 hours. Figure 6 is a graph of the results of the maintainability calculation of the Conveying Belt, Motor Drive, and Bearing.

3.5. Analysis of availability

Based on the results of the formulation of analytical availability on the RBD that has been done, the calculation of the availability of subsystems that exist from the UHF machine system is done using the World Class Maintenance Key Performance Indicator.

| Sub-system       | MTTF    | MTTR   | Availability | Performance Indicator (95%) |
|------------------|---------|--------|--------------|-----------------------------|
| Conveying Belt   | 1196.81 | 0.0905 | 99.99%       | Achieved                    |
| Drive Motor      | 1664.08 | 0.1246 | 99.99%       | Achieved                    |
| Bearing          | 1608.38 | 0.0657 | 100.00%      | Achieved                    |

In table 2, based on an evaluation conducted using the World Class Key Performance Indicator, the indicator of the Leading Indicator has reached the target of 95% (Achieved).

| Sub-system       | Operational Time | MDT   | Availability | Performance Indicator (95%) |
|------------------|------------------|-------|--------------|-----------------------------|
| Conveying Belt   | 4,284            | 1.885 | 99.96%       | Achieved                    |
| Drive Motor      | 4,284            | 0.122 | 100.00%      | Achieved                    |
| Bearing          | 4,284            | 2.011 | 99.95%       | Achieved                    |

In table 3, based on an evaluation conducted using the World Class Key Performance Indicator, the indicator of the Lagging Indicator has reached the target of 95% (Achieved).

3.6. Analysis of safety integrity level

The steps to find the value of Safety Integrity Level (SIL) are as follows:

- Find the lambda value ($\lambda$) for each component with the formula:
  \[ \lambda = \frac{1}{MTTF} \]  \(2\)

- Find the Probability Failure on Demand (PFD) value for each component with the formula:
  \[ PFD = \frac{\lambda \cdot T}{2} \]  \(3\)
Find the Risk Reduction Factor (RRF) value using the formula:

\[ RRF = \frac{1}{PFD} \]  

Information:
\( \lambda \): The Failure rate
\( T \): Testing Interval Time

Based on the results table the calculation of the PFD value is done at \( t = 239 \) hours or one working day and the RRF value is in the range of 10-100 that each component is in SIL 1.

| Component         | PFD    | RRF    | SIL |
|-------------------|--------|--------|-----|
| Conveying Belt    | 0.0998 | 10.015 | 1   |
| Drive Motor       | 0.0718 | 13.925 | 1   |
| Bearing           | 0.0743 | 13.459 | 1   |

### 4. Conclusion

From the results of data processing RAMS (Reliability, Availability, Maintainability, Safety Analysis) using Reliability Block Diagram modeling based on the analytical approach, for 120 hours, the system has a Reliability value (90.41%). The average value of the system Maintainability at \( t = 2 \) hours. Based on the world-class maintenance of Key Performance Indicators, leading indicators and lagging availability have reached the target indicator standard. Safety Integrity Level values from the calculation based on the PFD and RRF values for each system are in SIL 1.

### References

[1] Lundteigen M A, Rausand M and Utne I B 2009 Integrating RAMS engineering and management with the safety life cycle of IEC 61508 *Reliability Engineering & System Safety* 94(12) 1894-1903

[2] Rahmawati D N and Hs M I 2013 Evaluasi Reliability dan Safety pada Sistem Pengendalian Level Syn Gas 2ND Interstage Separator Di PT. Petrokimia Gresik *Jurnal Teknik ITS* 2(2) F312-F317

[3] Ebeling C E 1997 *An Introduction to Reliability and Maintainability Engineering* (Singapore: The McGraw-Hill Companies, Inc)

[4] Blanchard B S, Fabrycky W J and Fabrycky W J 1990 *Systems engineering and analysis* (NJ: Prentice Hall)

[5] Atmaji F T D 2015 Optimasi jadwal perawatan pencegahan pada mesin tenun unit satu di PT KSM, Yogyakarta *Jurnal Rekayasa Sistem & Industri (JRSI)* 2(02) 7-11

[6] Ebrahimi A 2010 Effect analysis of Reliability, Availability, Maintainability and Safety (RAMS) Parameters in design and operation of Dynamic Positioning (DP) systems in floating offshore structures.

[7] Kirana U T, Alhilman J and Sutrisno S 2016 Perencanaan Kebijakan Perawatan Mesin Corazza FF100 Pada Line 3 PT XYZ Dengan Metode Reliability Centered Maintenance (RCM) II *Jurnal Rekayasa Sistem & Industri (JRSI)* 3(01) 47-53

[8] Faizah R A 2015 *Analisis keandalan dan safety integrated level pada stripper PV-3900 di industri pengolahan minyak* (Doctoral dissertation, Institut Teknologi Sepuluh Nopember)