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Analysis of the Application of Reliability, Availability, and Maintainability (RAM) Method in CNC Plasma Cutting Machine Maintenance at PT XYZ

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Abstract

This study aims to analyze the application of the Reliability, Availability, and Maintainability (RAM) method in the CNC Plasma Cutting machine maintenance system at PT XYZ as one of the main equipment in the production process in the maritime industry, especially in shipyard companies. The analysis was conducted based on machine operational data during a one-year observation period which includes operating time, planned downtime, unplanned downtime, and the number of machine failure events. A quantitative approach was used to calculate the Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), and Availability parameters as indicators of machine maintenance performance. The analysis results show that the CNC Plasma Cutting machine has an MTBF value of 103.2 hours, an MTTR of 2.54 hours, and an availability of 98.71%. These values indicate that the machine has a high level of reliability and availability, and a maintenance system that is able to restore the machine's condition in a relatively short time after a disruption occurs. However, unplanned downtime is still found which has the potential to affect the effectiveness of machine operations. Overall, the application of the RAM method is able to provide a comprehensive picture of machine maintenance performance and can be used as a basis for evaluation in preparing more targeted and data-based maintenance policies to support the continuity of the production process in shipbuilding companies.

Keywords: *Availability; CNC Plasma Cutting; Maintainability; Reliability; RAM*

1. Introduction

The manufacturing and shipbuilding industries are characterized by complex, large-scale production processes, involving the use of production equipment with a high degree of precision and operational continuity. Each stage of the production process is integrated and forms a single, sequential workflow, so that disruptions to one machine can have a chain effect on the smooth running of subsequent processes. In these conditions, machine reliability and availability are key factors in maintaining production process stability and achieving company operational targets. If machine performance is not managed properly, the potential for downtime will increase and impact productivity declines, wasted time, and increased operational costs [1] .

Therefore, a machine maintenance system plays a crucial role in ensuring that production equipment is able to operate reliably over a specified period, is available when needed, and can be quickly restored when a disruption occurs. Systematic machine performance evaluation based on operational data is a crucial step in assessing the effectiveness of a maintenance system implemented in an industrial environment. A measurable evaluation approach is necessary so that the actual condition of machine performance can be objectively identified and used as a basis for making appropriate maintenance decisions [2].

PT XYZ is a company engaged in the maritime industry, specifically in shipbuilding activities. The ship production process at PT XYZ involves various interrelated fabrication stages, starting from material cutting, structural formation, to the assembly and final finishing process. One of the initial stages that plays a very crucial role is the steel material cutting process, which is carried out using a CNC Plasma Cutting machine. This machine is at the beginning of the production flow, so the level of reliability and availability is very important in determining the smoothness of the next production stages [3].

Operational disruptions that occur in CNC Plasma Cutting machines have the potential to cause production flow to stop from the initial stage, which in turn can impact project completion delays, decrease resource utilization efficiency, and disrupt the achievement of company production targets. In operational practice, CNC Plasma Cutting machines are not free from the potential for downtime, both planned downtime due to maintenance activities and unplanned downtime due to damage or technical disruptions. Downtime that occurs will reduce the effective operating time of the machine and directly affect the level of machine utilization in supporting the production process.

2. Research methodology

2.1. Research Approach

This study uses a descriptive quantitative approach with the aim of evaluating the operational performance and maintenance system of CNC Plasma Cutting machines in a shipyard company. The quantitative approach was used because the analysis was conducted based on numerical data in the form of machine operating time, downtime, and failure frequency obtained from historical operational data. The descriptive method was chosen to describe the actual condition of machine performance without manipulating the research variables, so that the analysis results reflect machine performance as it occurs in the field.

Machine performance evaluation was conducted using the Reliability, Availability, and Maintainability (RAM) approach, which is widely used in industrial research to assess the level of machine reliability, machine readiness to support the production process, and the effectiveness of the implemented maintenance system. The RAM approach was chosen because it is able to provide a comprehensive picture of machine performance based on actual operational data and disruption history, as applied to the analysis of production machine performance in various industrial sectors.

2.2. Object of Study and Data Collection

The object of this study is the CNC Plasma Cutting machine used in the initial stage of the steel cutting production process at a shipyard company, which is anonymized as PT XYZ in this journal. This machine has a strategic role in the production flow because it is at the initial stage of the fabrication process, so its performance greatly affects the smoothness of the subsequent production stages.

The data used in this study are machine operational data obtained from operation records and maintenance reports over a one-year observation period. The collected data include planned operation time, planned downtime, unplanned downtime, and the number of machine failures. All data are recorded in hours and used as the basis for evaluating machine performance, as is done in RAM analysis studies in the manufacturing and processing industries that use historical data as the primary source of analysis.

2.3. Data Analysis Procedure

Data analysis was conducted through several sequential stages to systematically describe the operational and maintenance performance of CNC Plasma Cutting machines. The initial stage of the analysis was carried out by processing downtime data to obtain the total machine downtime during the observation period, which includes planned and unplanned downtime. Next, the operating time data was used to determine the effective operating time of the machine available to support the production process. Based on the results of the processing of operating time data, a machine performance analysis was conducted using the Reliability, Availability, and Maintainability (RAM) indicators. The reliability parameter is used to describe the machine's ability to operate without failure, the maintainability parameter is used to assess the effectiveness of the repair process when a disruption occurs, while the availability parameter is used to assess the level of machine readiness to support production needs. This analysis approach follows the methodological flow commonly used in RAM studies, where the calculation and discussion of RAM indicator results are presented separately in the Results and Discussion section to provide a more in-depth interpretation of machine performance.

3. Results and Discussion

3.1. Data collection

The data used in this study is the operational data of CNC Plasma Cutting machines obtained during a certain observation period in the production process at a shipyard company. The data includes planned operation time, planned downtime, unplanned downtime, and the number of machine failures (number of failures) in monthly time units. This operational data is used as a basis for calculating total downtime, loading time, and operation time, as well as the main input in the Reliability, Availability, and Maintainability (RAM) analysis. A summary of the operational data of CNC Plasma Cutting machines per month is presented in Table 1.

Table 1: CNC Plasma Cutting Machine Operational Data

Month	Planned Operation (Hours)	Planned Downtime (Hours)	Unplanned Downtime (Hours)	Number of failure
December	264	4	5.2	3
January	428	4	4.8	3
February	432	5	7.5	5
March	272	4	4.6	3
April	369	5	5.2	4
May	371	4	5.8	5
June	254	3	2.2	2
July	336	4	2.6	2
August	446	4	4.5	4
September	419	3	3.9	3
October	434	5	6.2	5
November	446	5	4.1	3
Total	**4471**	**50**	**56.6**	**42**

Table 1 presents the operational data of CNC Plasma Cutting machines during the one-year observation period, starting from December to November, which shows variations in operating time and downtime in each month due to differences in machine usage intensity and maintenance activities. The total planned operation time for one year was recorded at 4471 hours, with planned downtime of 50 hours and unplanned downtime of 56.6 hours, where the relatively larger unplanned downtime value indicates that there are still operational disruptions outside the maintenance schedule. This condition has the potential to cause lost production time and affect the effectiveness of the use of CNC Plasma Cutting machines in supporting the shipyard production process, so this operational data is used as a basis for calculating total downtime, loading time, and operation time, as well as the main input in the Reliability, Availability, and Maintainability (RAM) analysis.

3.2. Calculation of Total Downtime, Loading Time, and Operation Time

Calculations of total downtime, loading time, and operation time were performed to determine the actual operating conditions of the CNC Plasma Cutting machine during the observation period. These calculations were based on operational data presented in Table 3.1 and used as the basis for evaluating Reliability, Availability, and Maintainability (RAM) performance.

Total downtime is calculated as the sum of planned downtime and unplanned downtime, as stated in Equation :

Total Downtime = Planned Downtime + Unplanned Downtime (1)

Loading time represents the time available for the machine to operate after deducting planned downtime, and calculated using Equation :

Loading Time = Planned Operation Time − Planned Downtime (2)

Operation time indicates the effective operating time of the machine and is obtained by subtracting unplanned downtime from loading time, as shown in Equation :

Operation Time = Loading Time − Unplanned Downtime (3)

Calculation of total downtime, loading time, and operation time produces quantitative data that describes the actual operating conditions of the CNC Plasma Cutting machine during the observation period. The calculated data are presented in Table 3.2 and used as the basis for evaluating Reliability, Availability, and Maintainability performance in the next subchapter.

Table 2: Calculation of Total Downtime, Loading Time, Operation Time

Month	Planned Operation (Hours)	Total Downtime	Loading Time	Operation Time
December	264	9.2	260	254.8
January	428	8.8	424	419.2
February	432	12.5	427	419.5
March	272	8.6	268	263.4
April	369	10.2	364	358.8
May	371	9.8	367	361.2
June	254	5.2	251	248.8
July	336	6.6	332	329.4
August	446	8.5	442	437.5
September	419	6.9	416	412.1
October	434	11.2	429	422.8
November	446	9.1	441	436.9
Total	**4471**	**106.6**	**4391**	**4334.4**

The calculation results in Table 3.2 show that downtime that occurred during the observation period had an impact on reducing the effective operating time of the CNC Plasma Cutting machine. Although the machine generally has a relatively high time utilization rate, the existence of downtime, especially unplanned downtime, still causes lost operating time that has the potential to affect the smooth running of the production process.

A comparison of loading time and operation time shows a relatively small time difference, indicating that most of the available time can be utilized for production activities. However, the presence of unplanned downtime remains a factor that needs to be considered because it directly impacts the effectiveness of machine operation. The resulting data is then used as the basis for a Reliability, Availability, and Maintainability (RAM) analysis to evaluate the performance and effectiveness of the CNC Plasma Cutting machine maintenance system.

3.3. Calculation of Reliability, Availability and Maintainability Values

Reliability, Availability, and Maintainability (RAM) analysis is used to evaluate the maintenance performance of CNC Plasma Cutting machines based on operational data and machine failure history during the observation period at a shipyard company.

1. Reliability Calculation (MTBF)

$$\text{MTBF} = \frac{Total\ Operation\ Time}{Total\ Number\ of\ failure} \quad (4)$$

$$\text{MTBF} = \frac{4334{,}4}{42}$$

MTBF = 103.2 hours

Based on the calculation results, the Mean Time Between Failure (MTBF) value of the CNC Plasma Cutting machine was 103.2 hours. This value indicates that the machine was able to operate in a relatively stable time interval before experiencing a disruption, so that the frequency of failures during the observation period was relatively low. This condition indicates that the machine's operating and maintenance system has been running quite well in maintaining the continuity of the production process. This relatively high MTBF value also reflects that the potential for operational disruptions that can stop the production process can be suppressed, so that the risk of production delays due to machine damage can be minimized. Thus, the reliability performance of the CNC Plasma Cutting machine during the observation period can be categorized as being in an adequate condition to support the shipyard's production needs.

2. Maintainability Calculation (MTTR)

$$MTTR = \frac{Total\ Hours\ of\ Downtime}{Total\ Number\ of\ failure} \quad (5)$$

$$MTTR = \frac{106,6}{42}$$

MTTR = 2.54 hours

The calculation results show that the Mean Time To Repair (MTTR) value of the CNC Plasma Cutting machine is 2.54 hours. This value indicates that the repair and recovery process of the machine after a disruption can be done in a relatively short time. This condition shows that the implemented maintenance system has been able to support efficient disruption handling. A low MTTR reflects the readiness of maintenance resources, both in terms of repair procedures, equipment availability, and spare parts support, so that downtime due to damage can be minimized. This has a positive impact on the smoothness of the production process because the machine can immediately return to operation after experiencing a disruption.

3. Availability Calculation

$$Availability = \frac{Operation\ Time}{Loading\ Time} \times 100\% \quad (6)$$

$$Availability = \frac{4334,4}{4391} \times 100\%$$

Availability = 0.9871 = 98.71%

Based on the calculation results, the availability value of the CNC Plasma Cutting machine was 98.71%, indicating that the machine had a very high level of operational readiness during the observation period. This value indicates that almost all available operational time can be utilized effectively to support the production process. The high availability value reflects that the implemented maintenance system is able to maintain a balance between operating time and machine downtime, so that machine availability remains at an optimal level. This condition has a positive impact on the smoothness of the production process because the risk of disruption due to machine unpreparedness can be minimized. With this level of availability, the CNC Plasma Cutting machine can be categorized as having excellent operational performance in supporting shipyard production needs.

3.4. Evaluation of Maintenance Performance Using RAM

Based on the results of operational data processing and the calculation of the Reliability, Availability, and Maintainability (RAM) indicators presented in the previous subchapter, it can be evaluated that the maintenance performance of the CNC Plasma Cutting machine is in good condition. The Mean Time Between Failure (MTBF) value of 103.2 hours indicates that the machine has adequate operational stability, so that the interval between failures is relatively rare during the observation period. This condition indicates that the implemented maintenance strategy is able to maintain machine reliability in supporting a continuous production process, although there is still unplanned downtime that needs to be further controlled.

In terms of maintainability, the Mean Time To Repair (MTTR) value of 2.54 hours reflects the maintenance system's ability to perform repairs quickly and efficiently when operational disruptions occur. This relatively short recovery time directly contributes to the high machine availability value of 98.71%, indicating that most of the effective operating time can be utilized for production activities. This high availability indicates that the machine is in a ready-to-operate condition for almost all available loading time.

Overall, the relationship between adequate MTBF, low MTTR, and high availability indicates that the CNC Plasma Cutting machine maintenance policy has been running effectively and is mutually supportive. However, the presence of unplanned downtime indicates potential for improvement through strengthening preventive maintenance and controlling factors that cause operational disruptions. Thus, the results of this RAM-based evaluation can be used as a basis for management decision-making to improve maintenance policies so that machine reliability and production process continuity can be maintained sustainably.

4. Conclusion

Based on the results of the internship and analysis of operational data on CNC Plasma Cutting machines using the Reliability, Availability, and Maintainability (RAM) approach, it can be concluded that the application of the RAM method is able to provide a comprehensive picture of the maintenance performance and operational condition of the machine. This analysis shows that the machine has a good level of reliability, ease of repair, and availability to support the smooth running of the production process. The evaluation results show that the implemented maintenance system is able to maintain the stability of machine performance, so that operational disruptions can be controlled and the recovery time after a disruption is relatively short. This condition has a positive impact on the high level of machine readiness for operation, which ultimately supports the continuity of the production process optimally. Overall, the RAM approach can be used as a basis for evaluation and decision-making in the preparation of more targeted and data-based maintenance policies. Although maintenance performance has been in good condition, the existence of unplanned downtime indicates the need to strengthen preventive maintenance strategies to improve machine reliability and maintain the sustainability of the production process in the future.

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