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Analysis of the Operational Safety of the Mechanical Arrangement of Parallel Lathes in the Mechanical Workshop of the Technical and Industrial Institute of Gombe (ITI GOMBE) and Choice of a Maintenance Policy

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ABSTRACT

This analysis of operational safety and the choice of a maintenance policy relates to the mechanical arrangement of parallel lathes in the workshop of the Technical and Industrial Institute of Gombe (ITI GOMBE).

This study is part of a reliability engineering approach aimed at improving the availability, maintainability, and safety of equipment used in educational and technical activities. It is based on the identification of the main mechanical components of parallel lathes, the analysis of failure modes, and the evaluation of reliability parameters using appropriate analytical and statistical methods.

The application of reliability tools, including failure analysis and the evaluation of indicators such as failure rate, mean time between failures (MTBF) and mean time to repair (MTTR), made it possible to diagnose the major causes of unavailability and to propose an optimal maintenance policy.

The results obtained lead to the recommendation of an improved predictive maintenance strategy, combined with planned corrective actions, in order to optimize the operational performance of parallel lathes, reduce costs related to unplanned shutdowns and ensure the sustainability of workshop equipment.

KEYWORDS: *Operational safety, Reliability, Maintainability, Availability, Maintenance policy, Parallel towers.*

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I. INTRODUCTION

Technological and industrial development relies heavily on the use of mechanical equipment capable of producing, transforming, and machining parts with precision. Among this equipment, machine tools occupy a central position in mechanical workshops, manufacturing industries, and technical training institutions.

These machines are essential elements in the manufacturing process, as they enable the transformation of raw materials into finished products that meet the required technical and dimensional specifications.

Among the most widely used machine tools is the parallel lathe, a fundamental piece of equipment in machining operations. It enables operations such as turning, threading, facing, drilling, and turning of mechanical parts. The parallel lathe is characterized by its versatility, precision, and ability to produce cylindrical parts with high accuracy.

In technical training institutions, such as the Gombe Industrial Technical Institute (ITI-Gombe), parallel lathes play a crucial educational and technical role. They allow students to acquire essential practical skills in the field of industrial mechanics.

However, like all mechanical equipment, these machines are subject to constraints related to their use, including wear, vibration, material fatigue and mechanical failures.

These phenomena can affect the performance, reliability, and availability of equipment, thus compromising its proper functioning. It therefore becomes essential to implement strategies to guarantee optimal operation. It is in this context that the concept of operational safety takes on its full importance.

In the mechanical workshop of the Gombe Industrial Technical Institute, parallel lathes are regularly used for student training and practical exercises. This frequent use puts significant stress on the mechanical components, which can lead to their gradual degradation.

Over time, certain mechanical components can fail due to wear, lack of lubrication, misalignment, or excessive mechanical stress. These failures can lead to:
- A decrease in machine performance,
- An increase in the frequency of breakdowns,
- A reduction in the lifespan of equipment,
- Machine unavailability,
- A disruption to educational activities.

Furthermore, the absence of a structured and appropriate maintenance policy can exacerbate these problems. Inadequate maintenance can lead to costly repairs, unplanned downtime, and accelerated equipment deterioration.

Faced with this situation, it becomes necessary to analyze the operational safety of the parallel towers of the ITI-Gombe workshop in order to identify the causes of the failures and to propose an appropriate maintenance policy.

The main question that arises is this:
- How should the operational safety of parallel lathes in the ITI-GOMBE mechanical workshop be analyzed and an appropriate maintenance policy developed to improve their reliability, availability and lifespan?

Secondary questions:
- Is it possible to identify the failure modes of mechanical components of parallel lathes in this workshop?
- Can the reliability and availability of equipment be subject to evaluation?
- Is there an adequate maintenance policy to evaluate the performance of these parallel towers?

Based on the preceding questions, the following hypotheses are formulated:
- We will analyze the operational safety of parallel lathes in the ITI-GOMBE workshop using technical means such as: FMEA, Fault Tree Analysis, and specialized software
- Following this analysis, based on the qualities of the maintenance strategies analyzed, we could develop the appropriate maintenance policy to improve their reliability, availability and lifespan.
- The failure modes of the mechanical components of these towers would be identified by subjecting them to appropriate diagnostics.
- Through a qualitative and quantitative analysis of operational safety, the reliability and availability of these machines could be assessed, as an appropriate maintenance policy would exist to determine their performance in:
  - First, defining the system under study (parallel tower) and its scope of study,
  - Defining the system (the machine alone or the entire workshop),
  - Describing the subsystems of the machine under study (spindle, gearbox, feed system, electric motor, lubrication system, etc.)

The main objective of this study is to analyze the operational safety of the mechanical arrangement of parallel lathes in the workshop of the Technical and Industrial Institute of Gombe in order to determine the most appropriate maintenance policy to ensure optimal operation of these (parallel lathes).

In addition to the main objective, the following specific objectives can be considered:
- Identify the various faulty mechanical components of the towers;
- Identify these failure modes of these components;
- Evaluate the reliability and availability of the equipment studied;
- Study the different applicable maintenance strategies;
- Propose a maintenance policy adapted to the parallel lathes of the ITGOMBE mechanical workshop.

Specifically, this study aims to:
- Identify the failure modes of mechanical components
- Evaluate the reliability and availability of equipment

- Review the existing maintenance policy in order to make a decision on which maintenance policy to propose.

This study is of significant interest on several levels:

From a scientific perspective: it contributes to the application of the concepts of operational safety and maintenance in the field of machine tools.

From a technical point of view: it makes it possible to identify the causes of failures and to propose solutions to improve the operation of machines.

From an economic perspective: an appropriate maintenance policy helps to reduce costs related to repairs and unplanned shutdowns.

From a pedagogical point of view: it contributes to improving the quality of technical training for students by ensuring the availability of equipment.

On a social level: this study makes it possible to reach a large segment of people interested in the concept of maintenance and operational safety.

The study is limited by three points of view, including:

A. From an epistemological point of view, the research is conducted in the field of production mechanics.
B. From a spatial point of view, it takes place in the ITI-Gombe mechanical workshop in the city of Kinshasa.
C. From a temporal point of view, the duration of our study was three years (2022-2025).

II. Methodological reference

In this work, we used paradigms related to both qualitative and quantitative methods. Our study variables concern the key factors determining the study: MTBF, MTTR, and Availability.

To achieve the set objectives, the following methods were used:

Direct observation of the machines constitutes the first step in diagnosing the system under study. It allows us to:

- Examine the actual condition of the parallel lathes by identifying cases of wear, vibration, abnormal noise, mechanical play, lubrication and alignment).
- Identify the actual usage practices by operators.
- Observe the environmental conditions (dust, humidity, overload).
- Identify visible defects and early warning signs of failures.

This phase allows the technical documentation to be compared with the reality on the ground and provides qualitative data essential for subsequent scientific analysis.

Functional analysis aims to precisely define:

- The main function of parallel lathes (machining by material removal).
- Secondary functions (guidance, power transmission, safety, lubrication).
- The interactions between the different subsystems (spindle, carriage, leadscrew, feed gearbox, bench).

It allows thus:

- Decompose the system into functional subsets.
- Identify the critical components.
- Understanding the links between component failure and overall performance loss.

This approach forms the basis for criticality analysis and reliability modeling.

Failure mode analysis, which is generally based on the FMEA (Failure Mode and Effects Analysis) method.

It consists of:

- Identify possible failure modes (spindle wear, leadscrew breakage, misalignment, bearing failures, etc.).
- Determine the probable causes of failures.
- Evaluate the effects on production and safety.
- Calculate the criticality index (severity × frequency × detectability).

This analysis allows us to:

Prioritize risks;

Target priority components for maintenance;

Propose appropriate preventative actions.

Reliability analysis, which aims to study the probabilistic behavior of failures over time, is used to:

- Determine the failure rate of the components.
- Calculate the key indicators (MTBF, MTTR, availability).
- Modeling failure laws (e.g., Wei-Bull law).
- Plan the optimal intervention times.

This step is fundamental for:

- Moving from corrective maintenance to optimized preventive maintenance.
- Improve operational availability.

- Reduce costs associated with unplanned shutdowns.

Conclusion

Our subject focused on the analysis of the operational safety of the mechanical arrangement of parallel lathes in the mechanical workshop of the technical and industrial institute of Gombe (ITI-GOMBE).

Given the importance of this production unit from a technical and educational point of view, we thought of carrying out a shock diagnosis on the operation of parallel lathes which constitute the largest part of all the machine tools that make up this workshop.

Our choice of parallel lathes over other machine tools (milling machines, drilling machines, grinding machines, etc.) is justified by the wide range of operations that can be performed on them. By analyzing the operational reliability of these machines (parallel lathes), we can ensure their optimal production and protect the operators working on them from risk.

As for the objectives assigned for this work, we can retain as the main objective the study and analysis of the operational safety of the parallel lathe arrangement of the ITI-GOMBE mechanical workshop is to determine the most appropriate maintenance policy to ensure optimal operation of these machines (parallel lathes).

Specifically, our study aims to:

- Identify the different critical components of parallel towers
- Analyze the operation of parallel towers
- Determine the failure modes of the identified components.
- Evaluate the reliability and availability of equipment
- Study the different maintenance strategies to apply to these machines
- Propose a maintenance policy adapted to the parallel lathes of the ITI-GOMBE mechanical workshop.

To achieve these objectives we used the following means:

- The analysis of the bathtub curve allowed us to determine the age of the different machines (parallel lathes) studied.
- FMEA (Failure Mode and Effects Analysis)
- The development of a specification document outlining the work steps.
- The use of computer-aided maintenance management for complete monitoring of equipment histograms.
- Recording incidents, their distribution, and associated costs,
- Anticipating preventive maintenance needs will optimize the use of human and material resources.

Finally, to determine the maintenance policy to be implemented in this workshop, we developed and optimized a decision-making model which served as our basis for doing so.

After this detailed study, we opted for predictive maintenance.

This maintenance strategy makes it possible to anticipate breakdowns by analyzing the actual condition of equipment using data collected in real time.

It relies primarily on data analysis, the IoT (Internet of Things) but also on artificial intelligence.

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