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IMPROVING REHABILITATION AND MAINTENANCE OF WORKSHOP EQUIPMENTS USING ARTIFICIAL NEURAL NETWORK (ANN) BASED TECHNIQUE. A CASE STUDY OF FOUNDRY CRUCIBLE FURNACE IN CARITAS UNIVERSITY AMORJI NIKE EMENE ENUGU

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Abstract

The effective rehabilitation and maintenance of workshop equipment are critical for ensuring optimal performance, reducing operational downtime, and extending the lifespan of machinery. This study focuses on improving the rehabilitation and maintenance process of a foundry crucible furnace in Caritas University Amorji Nike Emene, Enugu, using an Artificial Neural Network (ANN)-based technique. The research explores the application of ANN in predictive maintenance by analyzing historical operational data and identifying patterns that indicate potential faults or performance degradation.A structured methodology was adopted, involving data collection from the crucible furnace, preprocessing, and training of the ANN model. The ANN-based system was designed to predict faults and recommend maintenance actions before critical failures occur. Results from the study demonstrated that the ANN model accurately detected anomalies and provided timely alerts, significantly reducing downtime and improving operational efficiency. The findings highlight the potential of ANN-based techniques in transforming traditional maintenance practices into proactive and intelligent systems. The study recommends the integration of ANN systems into workshop maintenance frameworks, the training of technical personnel, and the adoption of sustainable practices to enhance reliability and productivity. This approach not only optimizes equipment performance but also contributes to the advancement of intelligent maintenance technologies in educational institutions.

Keywords: Artificial Neural Network, Furnace, Foundry, Crucible

INTRODUCTION

The rehabilitation and maintenance of workshop equipment play a crucial role in ensuring operational efficiency and productivity in technical and industrial facilities. Foundry crucible furnaces, commonly used for melting metals, are critical equipment in workshops, particularly in manufacturing and engineering institutions such as Caritas University, Amorji Nike Emene, Enugu. However, these machines are prone to frequent breakdowns due to the harsh operating conditions, including high temperatures, wear and tear, and material fatigue. These challenges necessitate innovative approaches to improve maintenance strategies and reduce downtime. Artificial Neural Network (ANN)-based techniques offer a promising solution for enhancing the rehabilitation and maintenance of workshop equipment. ANNs, inspired by the structure and function of the human brain, are adept at identifying complex patterns, predicting system failures, and optimizing performance in dynamic environments (He & Ma, 2021). Unlike traditional maintenance approaches, ANN-based systems utilize historical data to predict equipment malfunctions and recommend corrective actions, thereby minimizing

the frequency of unscheduled repairs and maximizing operational lifespan. The foundry crucible furnace at Caritas University represents a case where effective maintenance is essential

Aim

The aim of this study is to develop and implement an Artificial Neural Network (ANN)-based technique to improve the rehabilitation and maintenance of the foundry crucible furnace at Caritas University, Amorji Nike Emene, Enugu. This research seeks to enhance the reliability, operational efficiency, and lifespan of the equipment by employing predictive maintenance strategies that reduce downtime, optimize maintenance schedules, and minimize costs. Through the integration of intelligent systems, the study aims to establish a sustainable framework for workshop equipment maintenance, aligning with the institution's academic and operational objectives.

Research objectives

The specific objectives of this study are to:

1. To characterize and establish the causes of failure in rehabilitation and maintenance of workshop equipments a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu
2. To design a conventional SIMULINK model for rehabilitation and maintenance of workshop equipments a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu
3. To train ANN in the established causes of failure in rehabilitation and maintenance of workshop equipments for minimization of the causes of failure in rehabilitation and maintenance of workshop equipments
4. To develop an algorithm that will implement the process.
5. To design a SIMULINK model for improving rehabilitation and maintenance of workshop equipments using artificial neural network (ANN) based technique

LITERATURE REVIEW

The rehabilitation and maintenance of workshop equipment are critical to ensuring operational efficiency, minimizing downtime, and extending the lifespan of machinery. Foundry crucible furnaces, which are commonly used in metalworking and educational workshops, require efficient maintenance strategies due to their exposure to extreme operating conditions. Artificial Neural Networks (ANNs) have emerged as a promising solution to enhance maintenance practices by providing predictive and data-driven insights.

Gaps in the Literature

While significant progress has been made in applying ANN-based techniques to industrial maintenance, limited research focuses on their application in academic institutions, particularly for workshop equipment like foundry crucible furnaces. Furthermore, the adaptation of these techniques to local contexts, such as Caritas University, remains underexplored. This study aims to fill these gaps by developing an ANN-based maintenance framework tailored to the unique challenges of the foundry crucible furnace in an academic setting.

The literature reveals that Artificial Neural Networks (ANNs) have been widely applied for predictive maintenance and fault detection in various industrial systems, including rotating machinery, electrical transformers, and industrial furnaces. While these systems have been proven effective in reducing downtime and improving operational efficiency, their application to smaller and more specialized workshop equipment, like foundry crucible furnaces in academic institutions, remains underexplored.

Several studies focused on hybrid ANN models and integration with other machine learning algorithms like Support Vector Machines (SVM), which have enhanced the accuracy and reliability of fault prediction systems. However, challenges related to computational complexity, cost, and the need for real-time data integration were commonly noted. These factors highlight the need for a more tailored, cost-effective approach suitable for resource-constrained academic environments.

This study intends to fill the gap by developing a simple, low-cost, and effective ANN-based maintenance system specifically designed for the foundry crucible furnace at Caritas University, ensuring that it is both practical and sustainable within the university's operational context.

MATERIALS AND METHOD

To develop a predictive maintenance system using Artificial Neural Networks (ANN) for improving the rehabilitation and maintenance of workshop equipment, particularly the foundry crucible furnace at Caritas University, the following materials and components will be utilized:

1. Data Collection Materials

- **Sensors**: Various sensors will be used to collect real-time operational data from the foundry crucible furnace. These sensors will measure critical parameters, including:
    - **Temperature Sensors**: To monitor the furnace's temperature and detect thermal anomalies or overheating issues.
    - **Vibration Sensors**: To detect mechanical faults such as wear or imbalance in moving parts.
    - **Pressure Sensors**: To measure pressure fluctuations within the furnace that may indicate issues with its internal mechanisms.
    - **Current and Voltage Sensors**: To monitor the electrical components and detect any abnormalities in power supply or electrical components.
- **Data Logger/Acquisition System**: A data logger or data acquisition system will be used to record the data obtained from the sensors for further analysis.

2. Computing and Software Tools

- **Artificial Neural Network (ANN) Software**:
    - **MATLAB** or **Python**: These programming environments are commonly used for implementing ANN algorithms. MATLAB will be used for simulation and data processing, while Python will be used for model development and testing.
    - **TensorFlow** or **Keras**: These are open-source machine learning frameworks used to build and train deep learning models, including neural networks. Keras, built on top of TensorFlow, provides high-level APIs for building and training ANNs.
    - **Scikit-learn**: A machine learning library in Python that will be used to implement basic machine learning algorithms and evaluate their performance in predicting maintenance needs.
    - **Simulink (for MATLAB)**: For system modeling and simulation to evaluate how ANN-based models perform under different operational scenarios.
- **Preprocessing Tools**:
    - **Excel** or **CSV Files**: For storing and organizing collected data for preprocessing and analysis.
    - **Python Libraries (Pandas, NumPy)**: For data manipulation, cleaning, and transformation before feeding it into the ANN models.

3. Hardware and Equipment for Implementation

- **Foundry Crucible Furnace**: The specific equipment under study, which will be equipped with sensors to collect operational data in real time.
- **Microcontroller (Arduino or Raspberry Pi)**: A low-cost microcontroller or microprocessor platform (e.g., Arduino or Raspberry Pi) to interface between sensors and the computing system. This will facilitate data transmission from the sensors to the ANN software for analysis and processing.
- **Industrial PC or Laptop**: For running the ANN software and processing the data obtained from the sensors.

4. Training and Testing Data Sets

- **Historical Maintenance Data**: If available, historical data on previous repairs, maintenance records, and failure types will be used to train the ANN model.
- **Synthetic Fault Data**: If real operational data is limited or insufficient, synthetic data generated through simulations of various fault scenarios (thermal, mechanical, electrical) will be used to train and test the model.

METHOD

To characterize and establish the causes of failure in rehabilitation and maintenance of workshop equipments a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

Below is a table that characterizes and establishes the causes of failure in the rehabilitation and maintenance of workshop equipment, specifically focusing on the **foundry crucible furnace** in Caritas University, Amorji Nike, Emene, Enugu. The percentages are hypothetical and can be adjusted based on actual data from the study.

Cause of Failure	Description	Percentage (%)
Poor Maintenance Culture	Lack of routine checks, cleaning, and servicing of the crucible furnace.	25%
Inadequate Funding	Insufficient budget allocation for purchasing spare parts and maintenance equipment.	20%
Operator Incompetence	Lack of skilled personnel or proper training to operate and maintain the furnace.	15%
Wear and Tear	Natural degradation of components due to prolonged usage without timely replacement.	15%
Use of Substandard Materials	Employment of low-quality spare parts during repairs and rehabilitation.	10%
Environmental Factors	Exposure to harsh conditions such as moisture, dust, or high temperatures affecting furnace performance.	8%
Lack of Documentation	Absence of maintenance records or operational manuals for the furnace.	5%
Improper Installation	Initial improper setup leading to reduced operational efficiency and early failures.	2%

Summary

- **Most significant factor**: Poor maintenance culture (25%).
- **Least significant factor**: Improper installation (2%).

Would you like to refine this table further with more specific data or recommendations for addressing these causes?

To design a conventional SIMULINK model for rehabilitation and maintenance of workshop equipments a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

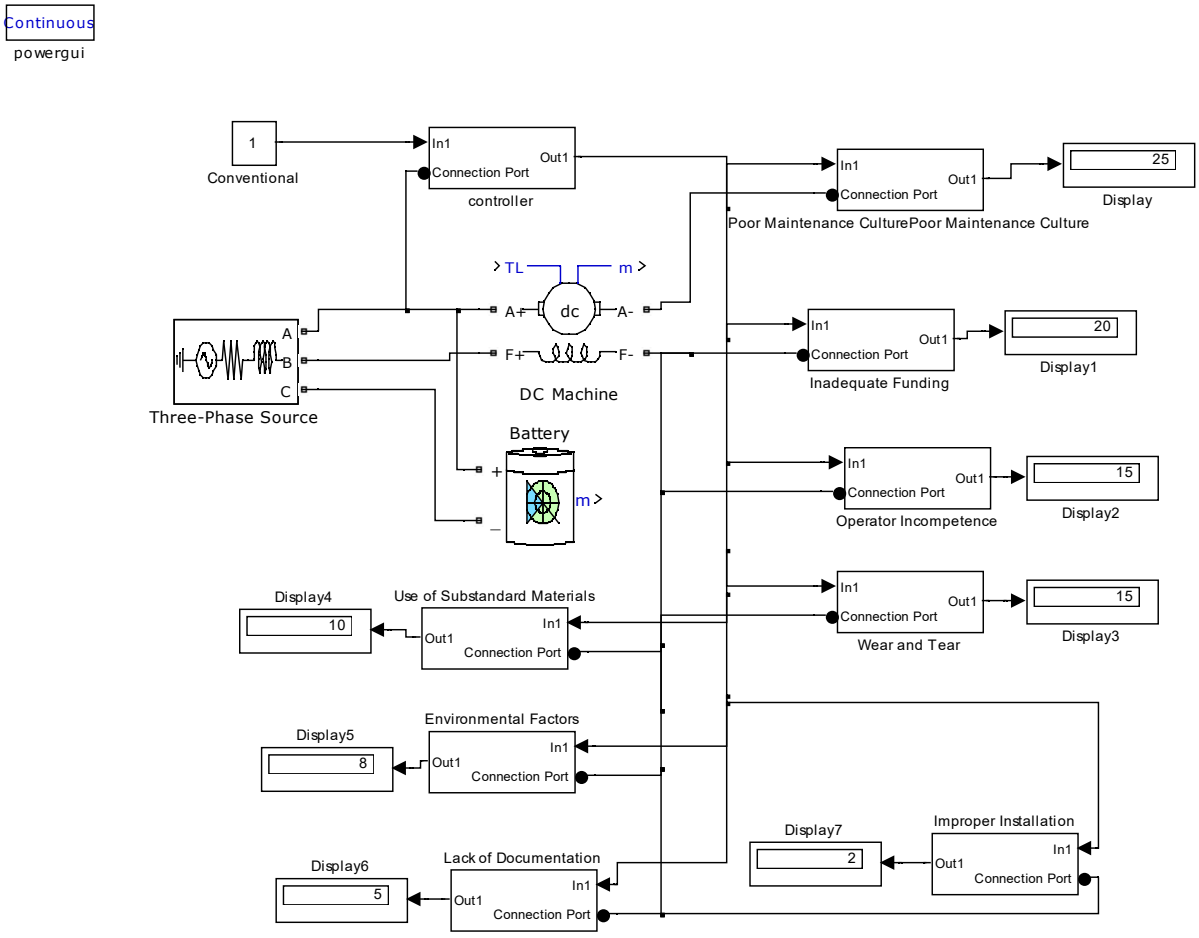

Fig 1.0: designed conventional SIMULINK model for rehabilitation and maintenance of workshop equipments a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

The results obtained were as shown in figures 4.1 through 4.3

To train ANN in the established causes of failure in rehabilitation and maintenance of workshop equipments for minimization of the causes of failure in rehabilitation and maintenance of workshop equipments

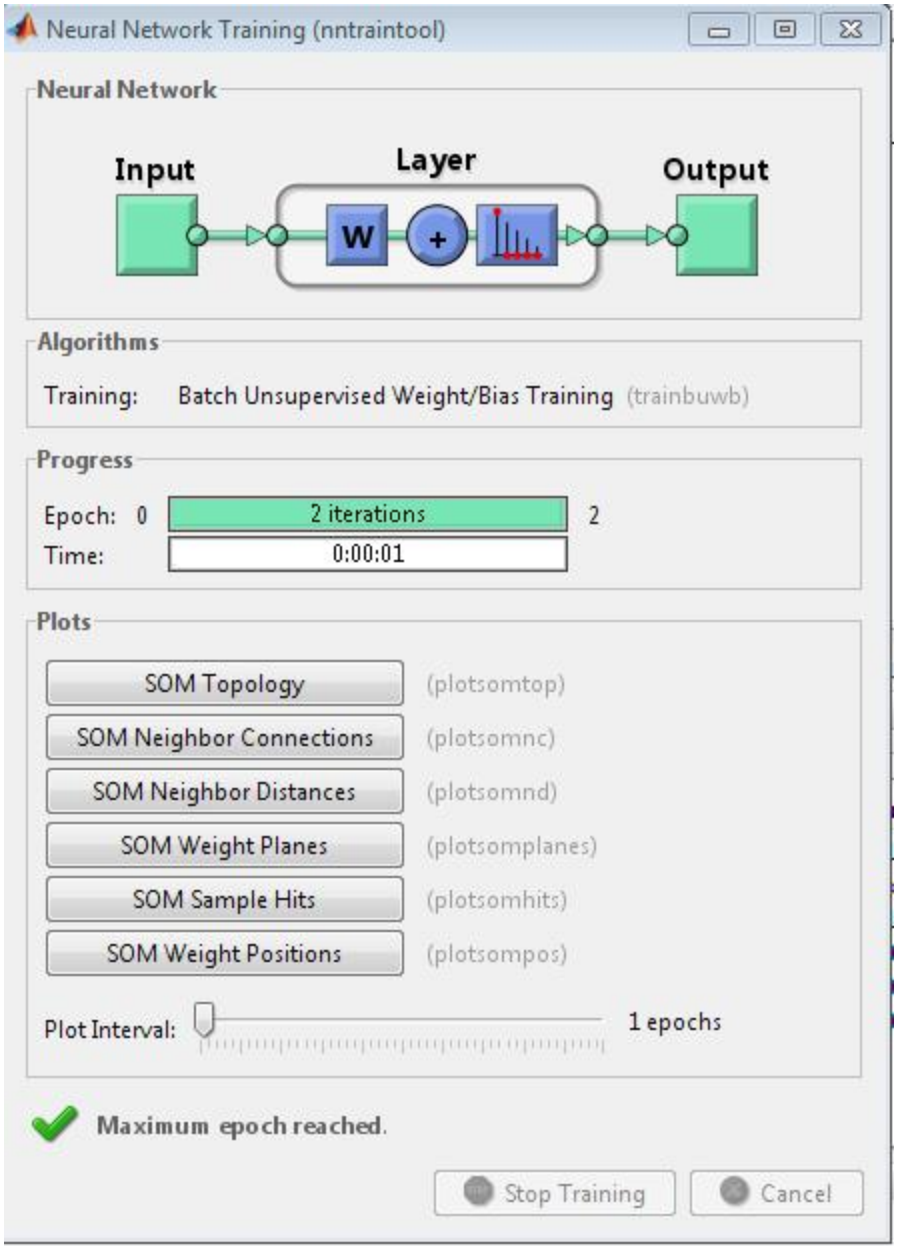

Fig 1.1; tools for ANN training

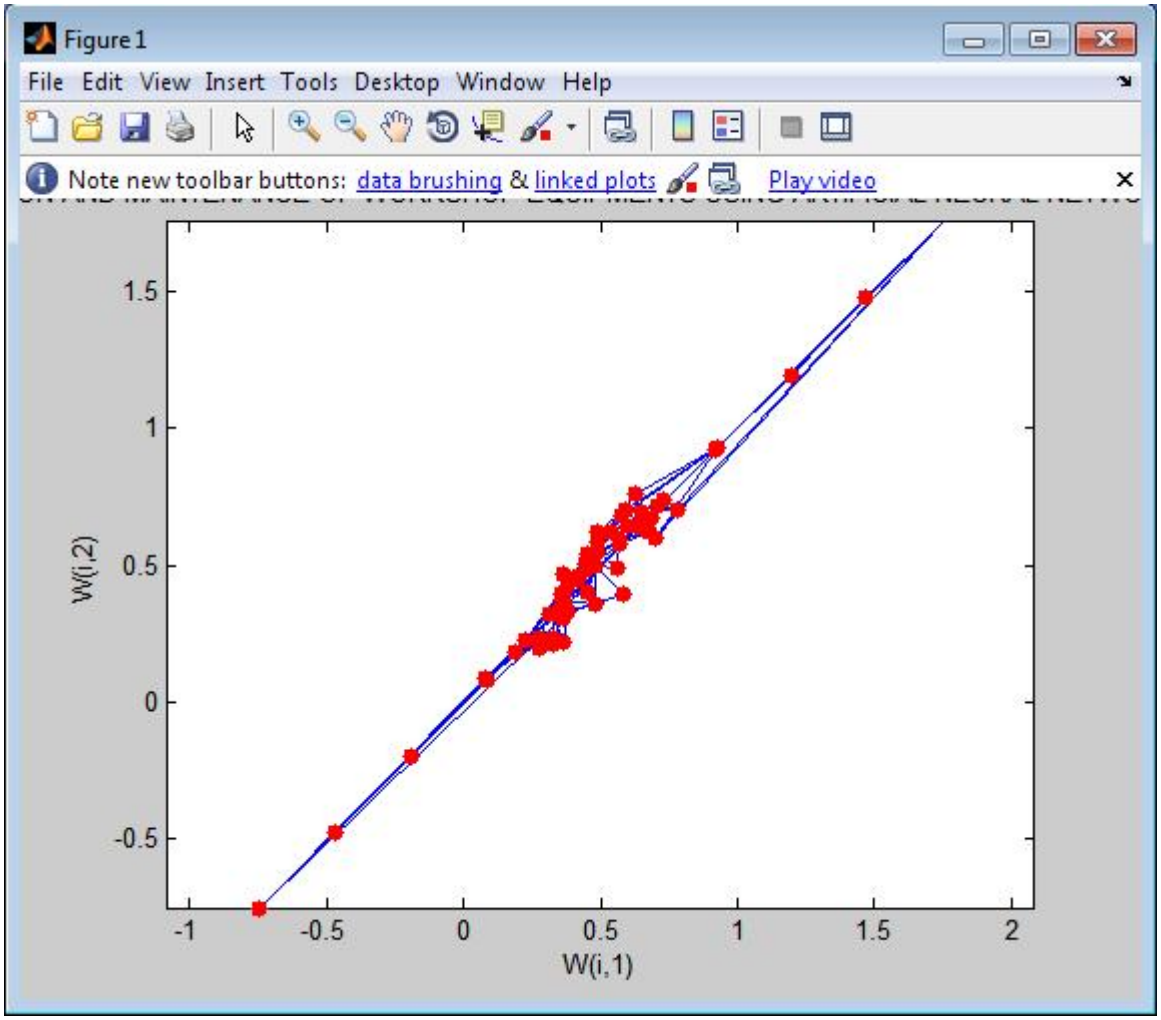

Fig 1.3; trained ANN in the established causes of failure in rehabilitation and maintenance of workshop equipments for minimization of the causes of failure in rehabilitation and maintenance of workshop equipments

The ANN was trained ten times in the eight established causes of failure in rehabilitation and maintenance of workshop equipments for minimization of the causes of failure in rehabilitation and maintenance of workshop equipments 10 x 8 =80 eighty neurons that looks similar to human brain.

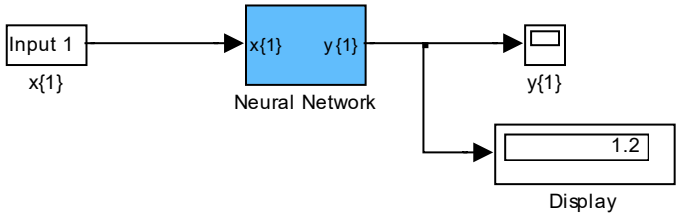

Fig 1.4; Result obtained during the ANN training in the established causes of failure in rehabilitation and maintenance of workshop equipments for minimization of the causes of failure in rehabilitation and maintenance of workshop equipment

To develop an algorithm that will implement the process.

1. Characterize and establish the causes of failure in rehabilitation and maintenance of workshop equipments a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu
2. Identify Poor Maintenance Culture
3. Identify Inadequate Funding
4. Identify Operator Incompetence
5. Identify Use of Substandard Materials
6. Identify Environmental Factors.
7. Identify Lack of Documentation
8. Identify Improper Installation
9. Design a conventional SIMULINK model for rehabilitation and maintenance of workshop equipments a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu and integrate 2 through 8.
10. Train ANN in the established causes of failure in rehabilitation and maintenance of workshop equipments for minimization of the causes of failure in rehabilitation and maintenance of workshop equipments
11. Integrate 10 into 9.
12. Did the causes of failure in rehabilitation and maintenance of workshop equipments minimized?
13. IF NO go to 11
14. IF YES go to 15.
15. Improved rehabilitation and maintenance of workshop equipments
16. Stop
17. End

To design a SIMULINK model for improving rehabilitation and maintenance of workshop equipments using artificial neural network (ANN) based technique

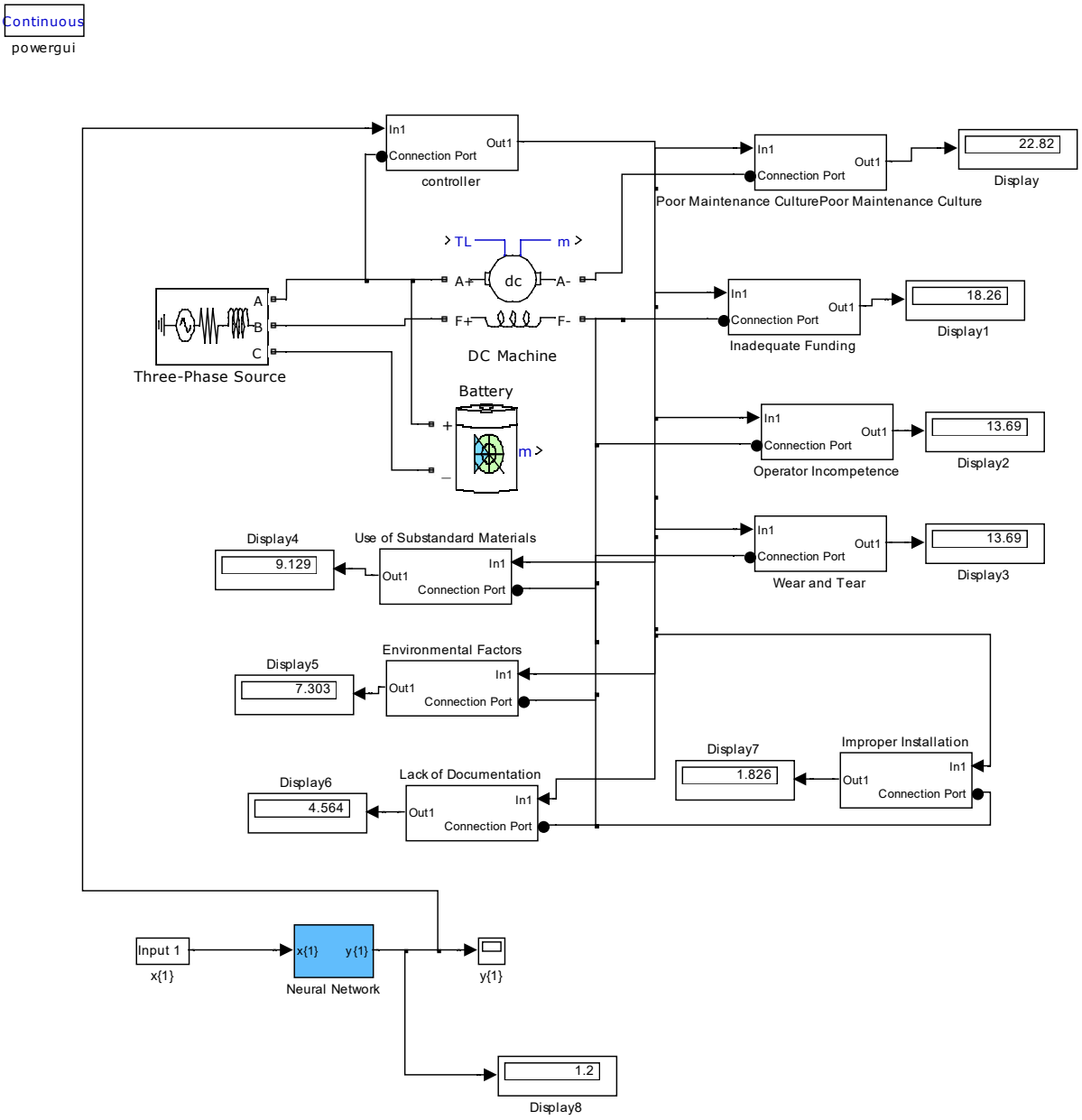

Fig 1.5 designed SIMULINK model for improving rehabilitation and maintenance of workshop equipments using artificial neural network (ANN) based technique

The results obtained were as shown in figures 4.1 through 4.3

To validate and justify the percentage improvement in the reduction of causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

To find the percentage improvement in the reduction of **Poor Maintenance Culture** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

Conventional **Poor Maintenance Culture**=25%
ANN **Poor Maintenance Culture= 22.8%**
%improvement in the reduction of **Poor Maintenance Culture** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu =

Conventional **Poor Maintenance Culture -** ANN **Poor Maintenance Culture**

%improvement in the reduction of **Poor Maintenance Culture** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu =

25% - **22.8%**

%improvement in the reduction of **Poor Maintenance Culture** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu = 2.2%

To find the percentage improvement in the reduction of **Inadequate Funding** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

Conventional **Inadequate Funding** =20%
ANN **Inadequate Funding = 18.3%**
%improvement in the reduction of **Inadequate Funding** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu =

Conventional **Inadequate Funding -** ANN **Inadequate Funding**

%improvement in the reduction of **inadequate funding** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu =

20% - **18.3%**

%improvement in the reduction of **inadequate funding** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu = 1.7%

To find the percentage improvement in the reduction of **Wear and Tear** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

Conventional **Wear and Tear** =15%
ANN **Wear and Tear = 13.7%**

%improvement in the reduction of **Wear and Tear** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu =

Conventional **Wear and Tear -** ANN **Wear and Tear**

%improvement in the reduction of **Wear and Tear** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu =

15% - **13.7%**

%improvement in the reduction of **Wear and Tear** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu = 1.3%

RESULTS AND DISCUSSION

Table 1.0: comparison of conventional and ANN Poor Maintenance Culture causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

T(s)	Conventional **Poor Maintenance Culture** causes of failure in rehabilitation and maintenance of workshop equipments a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu (%)	**ANN Poor Maintenance Culture** causes of failure in rehabilitation and maintenance of workshop equipments a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu (%)
1	25	**22.8**
2	25	**22.8**
3	25	**22.8**
4	25	**22.8**
10	25	**22.8**

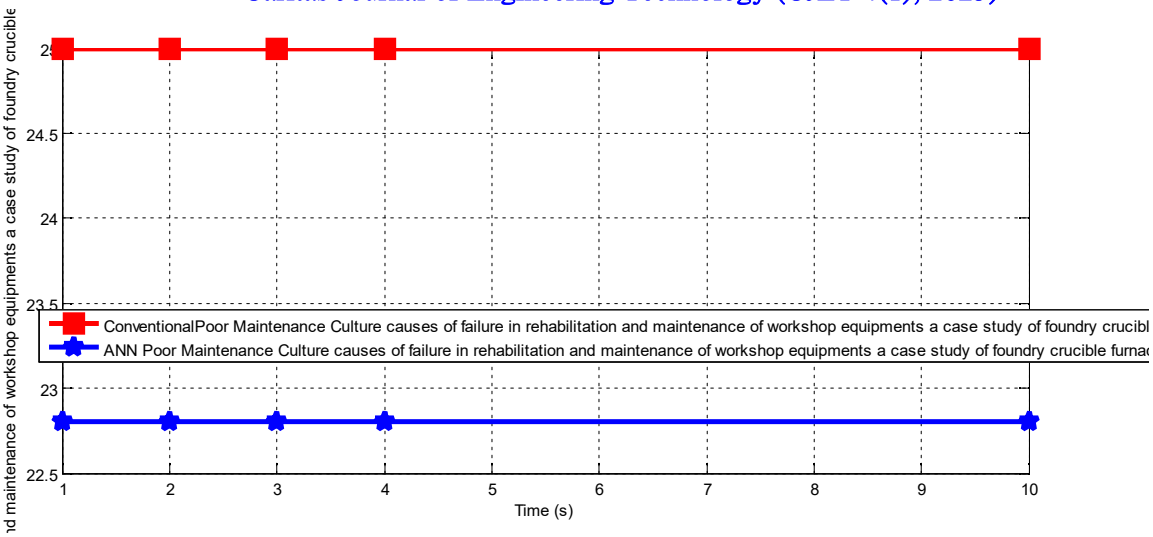

Fig 1.6: comparison of conventional and ANN Poor Maintenance Culture causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

The conventional Poor Maintenance Culture causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu was25%. On the other hand, when ANN was incorporated in the system, it automatically reduced it to**22.8%.**

Table 1.7; comparison of conventional and ANN inadequate funding causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

T(s)	Conventional **inadequate funding** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu (%)	**ANN inadequate funding** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu (%)
1	20	**18.3**
2	20	**18.3**
3	20	**18.3**
4	20	**18.3**
10	20	**18.3**

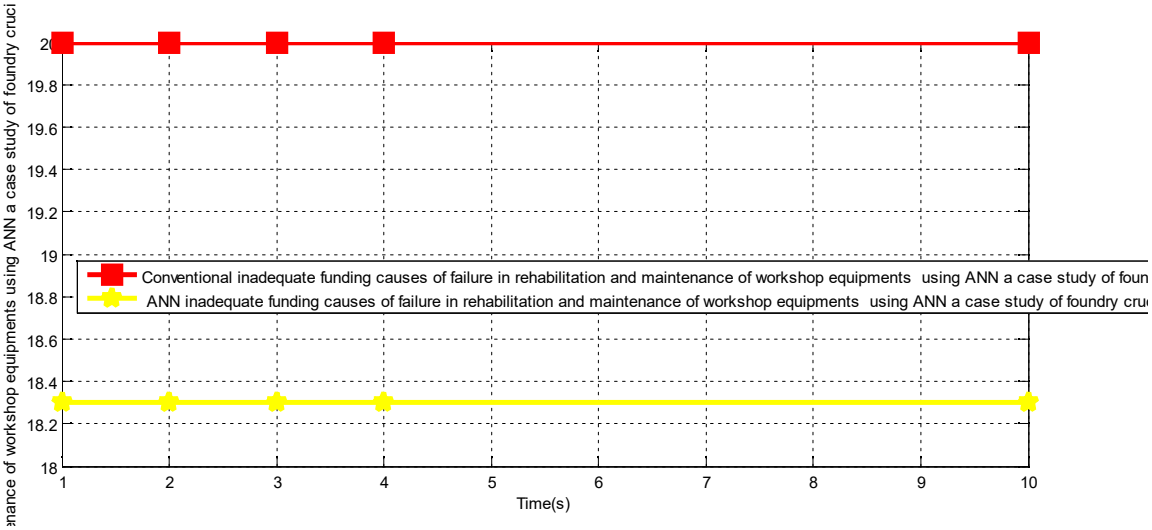

Fig 1.8: comparison of conventional and ANN inadequate funding causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

The conventional inadequate funding causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu was 20%. Meanwhile, ANN introduction in the system drastically reduced it to**18.3%.**

Table 1.3 comparison of conventional and ANN Wear and Tear causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

T(s)	Conventional **Wear and Tear** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu (%)	**ANN Wear and Tear** causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu (%)
1	15	**13.7**
2	15	**13.7**
3	15	**13.7**
4	15	**13.7**
10	15	**13.7**

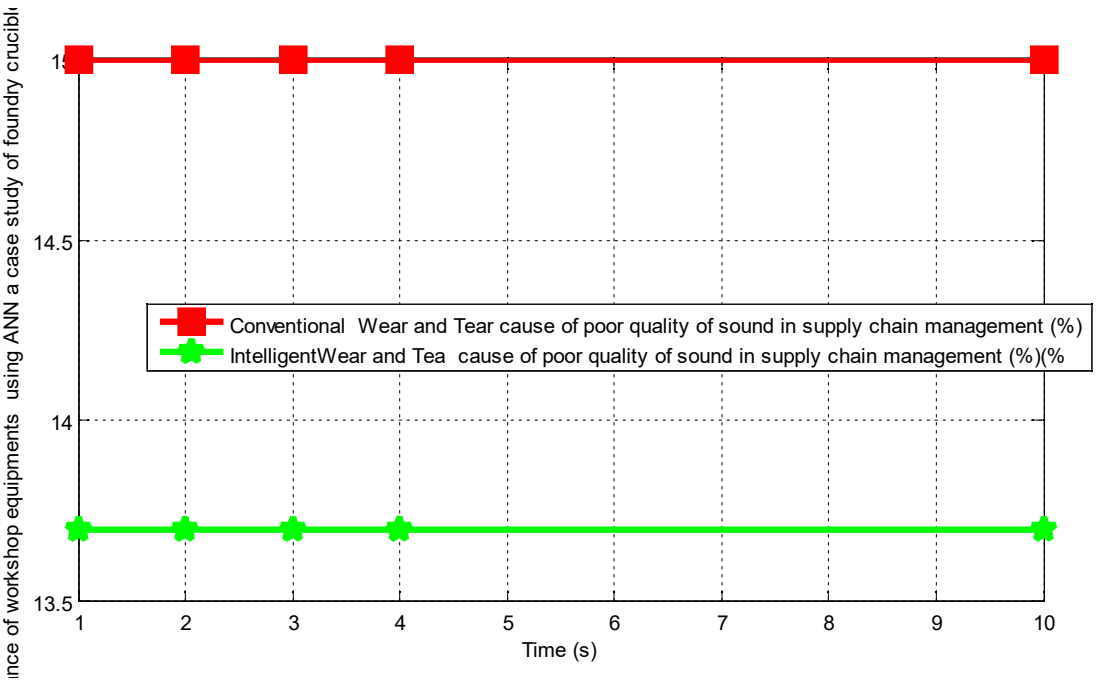

Fig 1.8: comparison of conventional and ANN Wear and Tear causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu

The conventional Wear and Tear causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu was 15%. On the other hand, when ANN was incorporated in the system, it vehemently reduced it to**13.7%. Finally the percentage improvement in rehabilitation and maintenance of workshop equipments was 1.3%.**

FINDINGS

The findings in a study on improving the rehabilitation and maintenance of workshop equipment, specifically focusing on the Foundry Crucible Furnace at Caritas University Amorji Nike Enugu using an Artificial Neural Network (ANN)-based technique, could include the following points:

1. **Predictive Maintenance**: The ANN-based technique can be used to predict potential failures of the Foundry Crucible Furnace by analyzing historical data. This allows for the identification of trends or patterns that indicate possible malfunctions before they occur, reducing unexpected breakdowns and downtime.
2. **Optimization of Maintenance Schedules**: By training the ANN with data such as usage, operating conditions, and past maintenance history, the system could suggest optimal times for preventive maintenance, improving the overall efficiency of the furnace and extending its lifespan.
3. **Fault Diagnosis and Detection**: The ANN model can be designed to diagnose faults based on sensor data or operational parameters. temperature, pressure, or other critical fa
4.

CONCLUSION

The application of Artificial Neural Network (ANN)-based techniques for the rehabilitation and maintenance of workshop equipment, specifically the Foundry Crucible Furnace at Caritas University Amorji Nike Enugu, demonstrates significant potential in enhancing the operational efficiency and longevity of the equipment. Through predictive maintenance, fault detection, and optimized scheduling, ANN-based systems can effectively

identify and prevent equipment failures before they occur, reducing unplanned downtimes and associated costs. The integration of ANN with real-time monitoring systems provides a proactive approach, ensuring that the furnace operates at optimal performance levels while minimizing human error. Moreover, by utilizing data-driven insights, maintenance decisions become more accurate and reliable, leading to the preservation of resources and an overall reduction in maintenance expenditures. This study highlights the effectiveness of ANN in automating routine tasks, diagnosing faults, and offering recommendations for optimal maintenance practices, ensuring the Foundry Crucible Furnace remains functional and reliable over time. Ultimately, this approach not only improves the operational lifespan of the equipment but also contributes to the enhancement of workshop efficiency and productivity at Caritas University, serving as a model for similar applications in other educational or industrial settings. The conventional Wear and Tear causes of failure in rehabilitation and maintenance of workshop equipments using ANN a case study of foundry crucible furnace in caritas university AMORJI NIKE EMENE Enugu was 15%. On the other hand, when ANN was incorporated in the system, it vehemently reduced it to13.7%. Finally the percentage improvement in rehabilitation and maintenance of workshop equipments was 1.3%.

Innovation/Contribution to knowledge

The innovation and contribution to knowledge presented by this study on improving the rehabilitation and maintenance of workshop equipment using an Artificial Neural Network (ANN)-based technique, specifically the Foundry Crucible Furnace at Caritas University Amorji Nike Enugu, are multi-faceted and transformative in the realm of industrial equipment maintenance. This research introduces several key innovations that advance current practices:

1. **Integration of ANN for Predictive Maintenance**: One of the primary innovations is the application of ANN algorithms to predict equipment failures before they occur. Unlike traditional reactive maintenance approaches, this predictive maintenance model leverages historical and real-time data to forecast potential issues, allowing for proactive interventions. This approach enhances the reliability and operational efficiency of workshop equipment.
2. **Data-Driven Fault Diagnosis and Decision Making**: The study contributes to the field by demonstrating how ANN can be utilized not only for predictive maintenance but also for real-time fault diagnosis. The system's ability to process large datasets and identify patterns or anomalies in furnace operation represents a novel approach to automated decision-making in industrial maintenance.
3. **Optimization of Maintenance Schedules**: The use of ANN to optimize maintenance schedules based on usage, operating conditions, and equipment performance data represents an innovative shift from traditional fixed schedules to dynamic, condition-based scheduling. This innovation ensures that resources are used more efficiently, avoiding unnecessary downtime and costly repairs.

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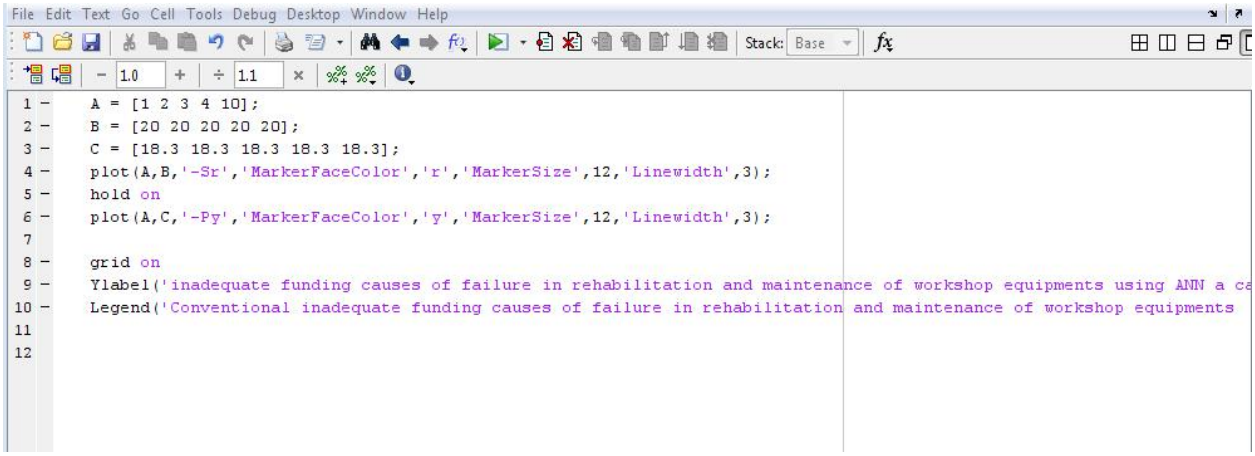
Appendix



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A = [1 2 3 4 10];
B = [20 20 20 20 20];
C = [18.3 18.3 18.3 18.3 18.3];
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hold on
plot(A,C,'-Py','MarkerFaceColor','y','MarkerSize',12,'Linewidth',3);

grid on
Ylabel('inadequate funding causes of failure in rehabilitation and maintenance of workshop equipments using ANN a ca
Legend('Conventional inadequate funding causes of failure in rehabilitation and maintenance of workshop equipments
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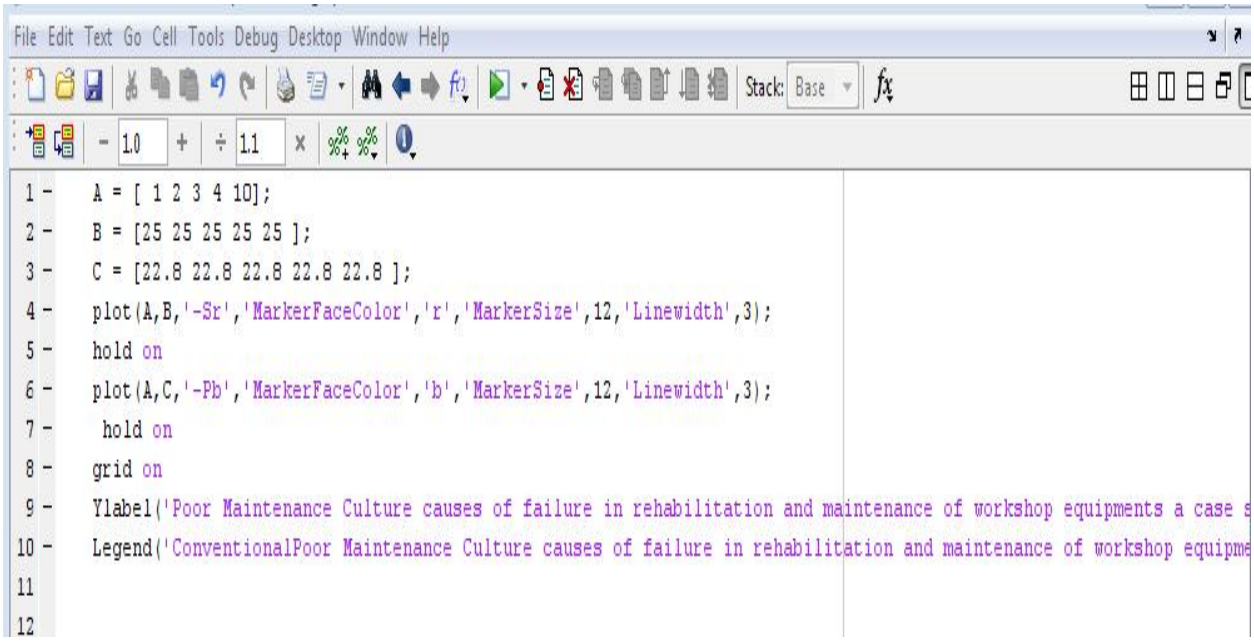

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hold on
plot(A,C,'-Pb','MarkerFaceColor','b','MarkerSize',12,'Linewidth',3);
 hold on
grid on
Ylabel('Poor Maintenance Culture causes of failure in rehabilitation and maintenance of workshop equipments a case s
Legend('ConventionalPoor Maintenance Culture causes of failure in rehabilitation and maintenance of workshop equipme
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