Available online www.unicrossjournals.com

UNICROSS JOURNAL OF SCIENCE AND TECHNOLOGY, UJOST

RESEARCH ARTICLE VOL. 3(2) JUNE 30, 2024 ISSN:2814-2233

Date Approved June 30, 2024 Pages 69 - 77

DEVELOPMENT OF A PROGRAMMABLE LOGIC CONTROLLER BASED METAL SORTING SYSTEM

Iliyasu Kayode OKEDIRAN[1], Wasiu Oyediran ADEDEJI[1], Abdulhafiz Ademola ADEFAJO[1], Musibaudeen Olatunde IDRIS[1], Babajide Joshua OJERINDE & Abideen Temitayo OYEWO[1]*

[1] Department of Mechanical Engineering, Osun State University, Osogbo, Osun State, Nigeria.

*Corresponding Author: Abideen Temitayo OYEWO (abideen.oyewo@uniosun.edu.ng)

Abstract

In today's world of rapid industrialization, the demand for effective sorting mechanisms is crucial to meet the surging production rates. This study delves into the integration of Programmable Logic Controllers (PLC) for metal detection and sorting processes. The envisioned systems employ PLC-controlled DC-geared motors, conveyor belts, proximity sensors, and pneumatic systems, creating a sophisticated setup for precise and automated sorting based on metallic properties. Performance evaluation was conducted to assess the traditional sorting system with the PLC of this study. There was improvement in the PLC derived from this study up to 43.7 – 46.3 %. This research significantly adds to the PLC applications, presenting a structured approach to streamline industrial processes, diminish reliance on manual labor, and elevate overall productivity.

Keywords: Programmable Logic Controllers (PLC), metal detection, automated sorting, productivity optimization.

1.0 Introduction

In the realm of modern industrial processes, the integration of automation technologies has become pivotal for enhancing efficiency and precision (Choudhary & Abidi, 2020; Kumar & Bhagyashri, 2018; Singh et al., 2016). A standout application in this domain is the Programmable Logic Controller (PLC) (Khaing et al., 2018), a digital computer designed to automate electromechanical processes (Haidong et al., 2019). Unlike conventional computers, PLCs are tailored for multiple inputs and output arrangements, offering extended temperature ranges, resistance to electrical noise, and durability against vibrations and impacts (Kayange & Mbonde, 2015).

This Metal Sorting System employs a sophisticated approach, utilizing precise ladder logic programs implemented in the PLC to govern the sorting process. The integration of proximity sensors adds an extra layer of accuracy, enabling the system to discern metallic properties with high precision (Thakur et al., 2021). As industries globally transition towards automation, our project aligns with the ethos of Low-Cost Automation (LCA) to optimize sorting processes efficiently. By combining mechanical components like conveyors and motors with PLC-controlled intelligence, we present a comprehensive solution to the challenges posed by modern industrial sorting needs. This project not only contributes to the efficiency of industrial processes but also holds promise for applications in waste management, mineral sorting, agricultural grading, and beyond (Bogar et al., 2021; Gaikwad et al., 2022). The utilization of PLCs as the central control unit ensures not only speed and performance but also reliability, making this Metal Sorting System a valuable asset in the evolving landscape of industrial automation (Oyewo et al., 2023; Singaravelan et al., 2021).

Researchers have delved into the application of Programmable Logic Controllers (PLCs) in the realm of metal detection and sorting. These investigations frequently delve into the incorporation of microcontrollers alongside sensors and various components to accomplish meticulous and automated metal detection. Mathivanan (2020) examined the utilization of a Raspberry Pi microcontroller in the development of a metal sorting system applied to the food industry. Similarly, Al Fahim et al. (2023) concentrated on employing an Arduino microcontroller to create a metal detector system (Mujiarto et al., 2020). Both projects successfully identified metals for diverse applications, demonstrating the efficiency and accuracy of their respective systems. Nevertheless, a drawback lies in the potential inadequacy of the chosen controllers to withstand harsh industrial conditions, including vibrations, heat, noise, etc (Rallabandi et al., 2023).

The project focuses on harnessing the power of PLCs in the development of a Metal Sorting System. The manufacturing industry, driven by the need for increased productivity (Alnema et al., 2023), reduced manual labor, and uniformity in manufacturing, demands robust sorting mechanisms. Industries often struggle with the sorting of objects based on dimensions, colors, weight, and, notably, metallic properties (Adebimpe et al., 2022; Debnath et al., 2023). Traditional sorting methods struggle to keep pace with rising production rates and diverse product variations. This study proffer solution that involves the strategic use of PLC-controlled systems, including DC motors, conveyor belts, and sensors, to systematically and accurately sort metallic objects. The aim is to provide an automated solution for the segregation of metal and non-metal materials, addressing the challenges posed by contemporary industrial sorting requirements.

2.0 Materials and methodology

The system comprises a 24VDC FX-1N24MR Mitsubishi PLC, an inductive metal detector, a proximity sensor, a DC motor, and push buttons, as illustrated in Figure 1. Table 1 also shows the list of materials used and PLC address assigned to each component.

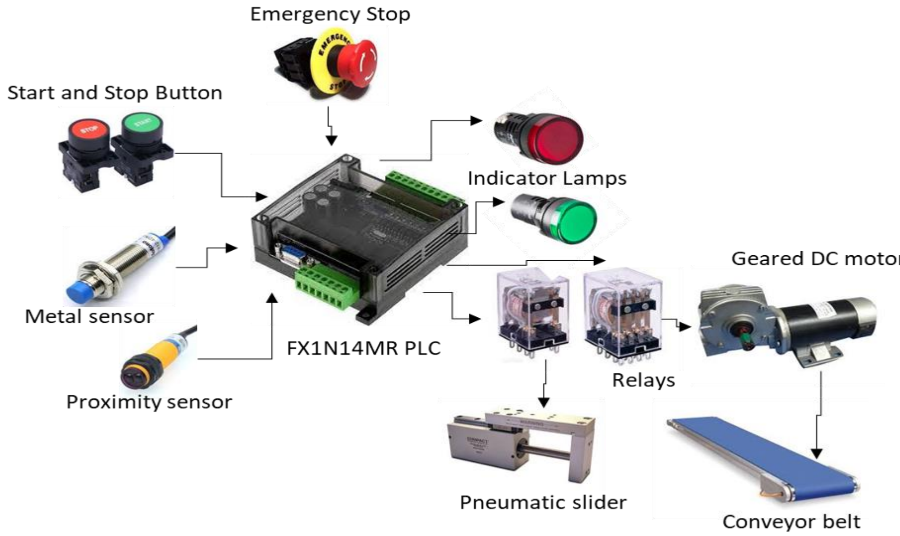

Figure 1: Component configuration of PLC Based metal sorting system

Table 1: Materials used and PLC address assigned

S/N	Components	Alias	PLC -Address	Ratings	Contact
1	Start Push button	STR	INPUT-X001	24VDC	NO
2	Stop Push button	STP	INPUT-X002	24VDC	NC
3	Metal sensor	MS	INPUT-X002	24VDC	NC
4	Proximity Sensor	PR	INPUT-X003	24VDC	NC
5	Conveyor motor	MTR	OUTPUT- Y000	24VDC	N/A
6	Pneumatic Slider	PNS	OUTPUT- Y001	24VDC	N/A
7	Green LED	ON	OUTPUT- Y002	24VDC	N/A
8	Red LED	OFF	OUTPUT- Y003	24VDC	N/A

At the core of the design is the 24VDC Mitsubishi PLC (FX1N24MR), providing 8 digital input and 6 digital output terminals to interface with sensors and actuators. The conveyor belt serves as the transportation medium for objects to be sorted, running from one end to another. Positioned along the conveyor belt is an inductive metal sensor designed to detect metallic objects. This sensor operates by generating a stable frequency, which is disturbed when a metal object is in proximity, distorting the frequency. When this distortion surpasses the predetermined threshold, a logic signal of 1 is sent to the PLC, which stores this signal in an address memory. As the conveyor continues its motion, when an object approaches the second proximity sensor, functioning as an object detector, a logic signal of 1 is sent to the PLC. The PLC then compares this logical signal from the proximity sensor with the one from the inductive sensor. If the result is 1, indicating both metal detection and object presence, a pneumatic slider is activated. The slider propels the metallic object off the conveyor belt into a designated container.

Conversely, if the logical operation yields a result of 0 (indicating no metal detection), the belt continues to roll, and the object naturally falls off at the end of the belt into a separate container. This process effectively segregates metallic and non-metallic objects. The system incorporates start, stop, and emergency stop buttons to control its operation. Refer to Figures 2 and 3 for the block diagram and operational flow chart.

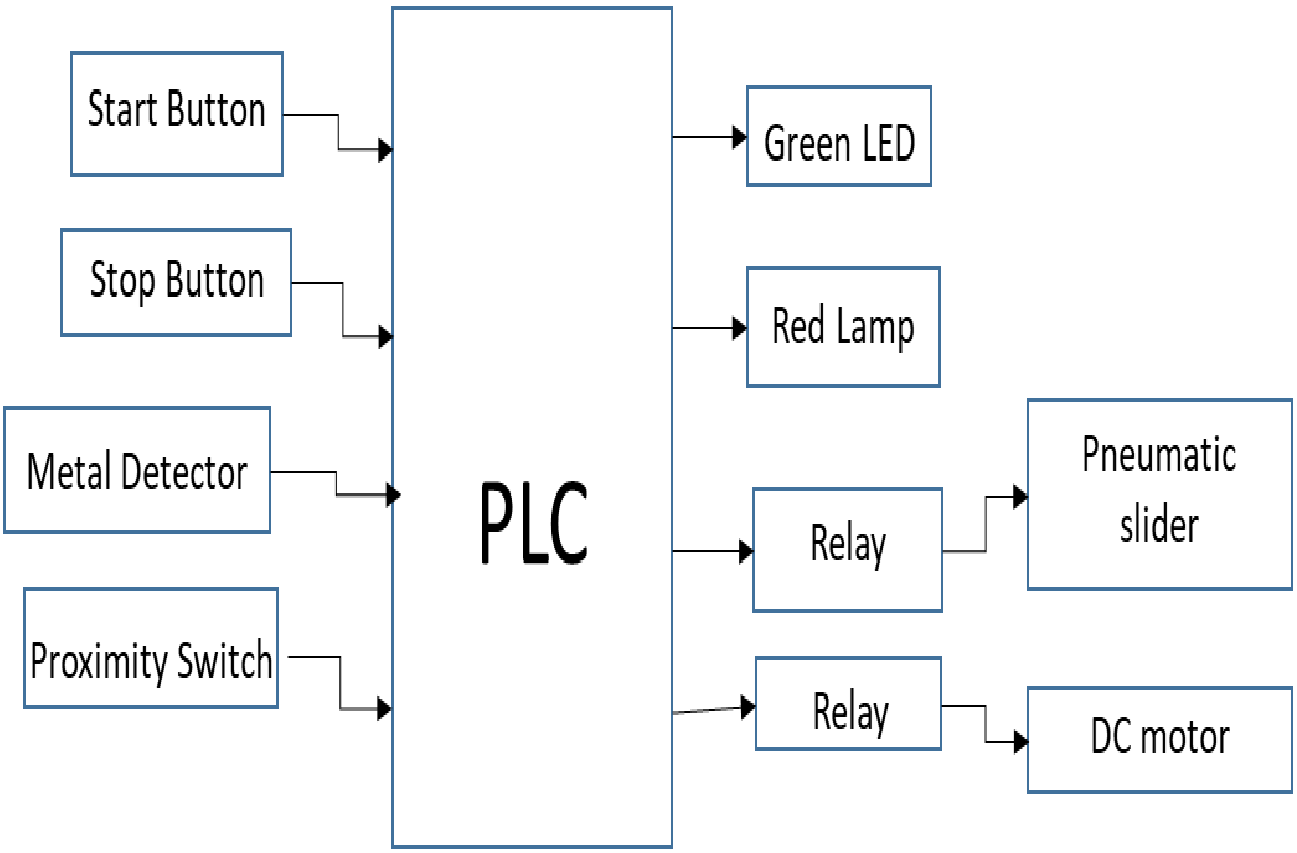

Figure 2: System block Diagram

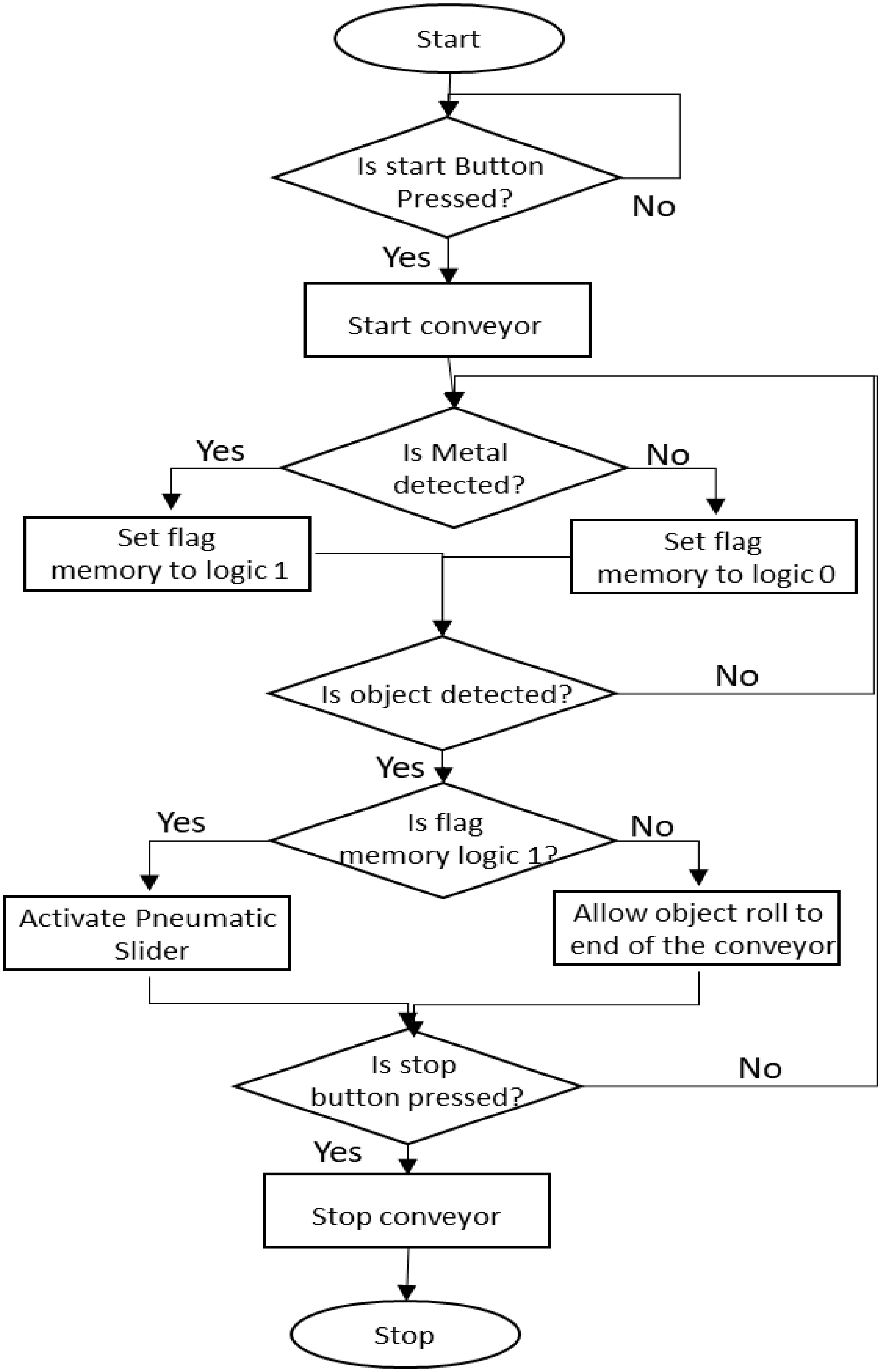

Figure 3: Flowchart for PLC based Metal Sorting System

3.0 Results and discussion

The integration of Programmable Logic Controllers (PLC) with proximity sensors and inductive metal detectors enabled the precise detection of metallic properties in the sorting process. The system exhibited exceptional accuracy in identifying metallic objects, showcasing its reliability in industrial applications where precision is paramount. During testing, the PLC accurately interpreted signals from sensors, ensuring consistent and dependable sorting based on predetermined criteria. This high level of accuracy is crucial for optimizing sorting processes and maintaining product quality standards in industrial settings.

One of the key strengths of the PLC-based metal sorting system lies in its functionality and flexibility. The ladder logic program effectively governed the movement of objects, allowing for seamless operation and precise sorting based on metallic properties. Moreover, the system demonstrated versatility in handling variations in object dimensions and characteristics, showcasing its adaptability to diverse industrial environments. This flexibility not only enhances operational efficiency but also facilitates the integration of the system into existing production lines with minimal disruption.

Five different metal combination were sourced, and were sorted by PLC of this study. Comparison was made with the traditional sorting method in term of time required for the task performed. Similar quantity was chosen for all the combinations, that is, 200 g. Table 2 highlights the comparison between the traditional sorting technique and the one derived in this study.

Table 2: Comparison between the traditional sorting technique and this study

Metal combination	Traditional sorting technique (min)	This study (min)	Efficiency of this study (%)
Combination 1	9.15	5.11	44.3
Combination 2	9.40	5.20	44.6
Combination 3	9.50	5.10	46.3
Combination 4	9.25	5.20	43.7
Combination 5	9.10	5.05	44.5

The efficiency of the PLC device revealed that there was great improvement compared with the traditional sorting method. This efficiency was found to be with 43.7 – 46.3 %. To further illustrate the performance of the PLC-based metal sorting system, a comparison table can be constructed to contrast its key features and capabilities with traditional sorting methods or alternative technologies. The

Table 3 provides a comparative analysis based on factors such as accuracy, reliability, functionality, and adaptability.

Table 3: Comparison between PLC-Based Metal Sorting System and Traditional Sorting Methods

Features	PLC-Based Metal Sorting System	Traditional Sorting Methods
Accuracy	High	Moderate to High
Reliability	Excellent	Variable
Functionality	Versatile	Limited
Adaptability	High	Limited
Maintenance Requirements	Low	Moderate to High
Initial Investment Cost	Moderate	Variable
Operational Efficiency	High	Moderate to High
Integration Complexity	Moderate	High

In summary, the results of the testing phase reaffirm the effectiveness and efficiency of the PLC-based metal sorting system in industrial applications. The system's high accuracy, reliability, functionality, and adaptability make it a valuable asset for streamlining sorting processes and enhancing overall productivity. By leveraging PLC technology, industries can achieve precise and automated sorting, reducing reliance on manual labor and minimizing errors. Moving forward, further research and development efforts could focus on optimizing the system's performance, expanding its capabilities, and exploring potential integration with emerging technologies for even greater efficiency and effectiveness in industrial sorting operations.

4.0 Conclusions

In summary, the investigation into the application of Programmable Logic Controllers (PLCs) in metal detection and sorting emerges as a promising avenue for advancing industrial processes. The integration of microcontrollers with sensors, as evidenced in several studies, underscores the potential for accurate and automated metal detection. Nevertheless, it is essential to recognize the limitations of specific controllers when exposed to demanding industrial conditions. To enhance the functionalities of the metal sorting system, diverse improvements can be contemplated to measure the weight, height, color, and count of objects. The integration of load cells or weight sensors into the conveyor belt facilitates the measurement of object weight, proving advantageous for the efficient sorting of objects based on their mass. Additionally, the inclusion of ultrasonic or laser sensors offers a means to measure the height of objects, contributing to the sorting process based on dimensional attributes. For improved object identification, the system can be equipped with color sensors or cameras endowed with image processing capabilities. This enhancement holds particular value, especially in industries where color serves as a crucial parameter for sorting.

References

Adebimpe, A., Uguru-Okorie, D., & Oluwagunwa, E. (2022). Design and production of an automatic solid waste sorting machine with smart digital counter. *Nigerian journal of technology*, *41*(3), 542-546.

Al Fahim, A., Rahman, M. M., Hridoy, M. W., & Uddin, K. R. (2023). Development of a PLC Based Automation Cell for Industry. *Journal of Integrated and Advanced Engineering (JIAE)*, *3*(2), 87-100.

Alnema, Y. H., Musaa, A. K., Ali, M. N., & Muhammad, A. O. (2023). Design and Simulation of an Automated Production Plant and Warehouse Management System. 2023 International Conference on Engineering, Science and Advanced Technology (ICESAT),

Bogar, A. B., Gaikwad, A. P., Patil, A. A., Kharade, O. D., Patil, S. B., & Shinge, V. R. (2021). Magnetic And Non-Magnetic Material Sorting Machine By Using PLC. *Journal of Emerging Technologies and Innovative Research (JETIR)*, *8*(6), 523-530.

Choudhary, A., & Abidi, S. B. (2020). PLC based Sorting System using Metal Detection. *International Research Journal of Engineering and Technology (Irjet)*, *7*(4), 6350-6355.

Debnath, T., Nazir, M. I., Podder, P. K., & Sarker, S. (2023). Design and implementation of a novel dust collector controller for powder production industry. *World Journal of Advanced Research and Reviews*, *18*(3), 1323-1331.

Gaikwad, N. S., Lad, M. M., Patil, S. S., Chavan, S. B., & Dalavi, G. S. (2022). Design and Manufacturing of Metal & Non-metal Sorting Using Metal Detector. *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, *10*(7), 485-487.

Haidong, Z., Lingling, J., Jianyi, W., Wei, W., Xiaokan, W., & Zhiguo, L. (2019). Automatic Text System Based on PLC for Walk-Through Metal Detector. IOP Conf. Series: Materials Science and Engineering,

Kayange, D. S., & Mbonde, N. (2015). An Automatic Circuit Design for Metal Detector by Using Programmable Logic Controller Technique. *International Journal of Engineering Science and Innovative Technology (IJESIT)*, *4*(1), 329-337.

Khaing, M. W., Win, A. M., & Aye, D. T. (2018). Automatic Sorting Machine. *International Journal of Science and Engineering Applications*, *7*(8), 138-142.

Kumar, H. P., & Bhagyashri. (2018). AUTOMATIC MATERIAL SEGREGATION SYSTEM USING PLC. *International Journal of Software & Hardware Research in Engineering*, *6*(9), 20-24.

Mathivanan, K. (2020). PLC Based Automatic Cutting Machine. *International Journal of Innovative Science and Research Technology*, *5*(11), 2456-2165.

Mujiarto, Sambas, A., & Haerudin, I. (2020). Design of Arduino-Based Metal Detector Robot. *Solid State Technology*, *63*(6), 12401-12411.

Oyewo, A. T., Oluwole, O. O., Ajide, O. O., Omoniyi, T. E., & Hussain, M. (2023). A summary of current advancements in hybrid composites based on aluminium matrix in aerospace applications. *Hybrid Advances*, 100117.

Rallabandi, S. R., Yanda, S., Rao, C., Ramakrishna, B., & Apparao, D. (2023). Development of a color-code sorting machine operating with a pneumatic and programmable logic control. *Materials Today: Proceedings*.

Singaravelan, A., Mahesh, M., Ramachandra, R., Sriram, S., Gunapriya, B., & Ganesh, C. (2021). PLC-Based Fire Accident Prevention System. Advances in Automation, Signal Processing, Instrumentation, and Control: Select Proceedings of i-CASIC 2020,

Singh, D., Jain, A., & Mahapatra, S. (2016). Metal Sensing Automation. *International Journal of Hybrid Information Technology*, *9*(1), 423-430.

Thakur, S., Joshi, D., Tiwari, O., Sarmalkar, K., & Tripathi, A. (2021). Metal Elimination System using PLC. *International Journal of Engineering Research & Technology (IJERT)*, *9*(3), 725-729.