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Design of an Automatic Slat Conveyor Prototype Based on PLC

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ABSTRACT

The transfer of goods, commonly known as pick and place, which still relies on manual labor, poses challenges for industrial production companies. In automotive quality inspection, the manual transfer of vehicles by drivers between inspection stations often leads to inefficiencies and missed production targets. This research aims to implement an automated slat conveyor system controlled by PLC to optimize vehicle quality inspection. With this system, vehicles are moved automatically between stations, allowing inspections to be conducted during transit. The automation aligns with the Kaizen philosophy, emphasizing continuous improvement in production processes. The results of testing the slat conveyor automation system indicate that the system successfully achieves a maximum response time of 0.8 seconds, with a speed of 0.6 meters per second.

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1. INTRODUCTION

The process of transferring goods from one area to another, also known as pick and place, remains a significant challenge for industrial production companies when it relies heavily on manual labor [1]. This limitation has driven industries to adopt automation components, such as conveyors, to replace human operators [2]. A conveyor is a mechanical device used to transfer goods or materials from one location to another automatically over a certain distance [3]. This system is widely utilized in manufacturing, warehousing, logistics, and various other sectors to enhance efficiency, reduce processing time, and minimize reliance on manual labor [4].

Conveyor capacity varies widely depending on several factors, including the objects being transported, conveyor width, length, and the motor power required to move objects over a designated distance [5]. Among various conveyor types, slat conveyors stand out as a specialized system designed to transport heavy and bulky items [6]. Additionally, slats can be uniquely shaped to accommodate a wider range of applications compared to other conveyor systems [7].

A slat conveyor is a type of conveyor that uses rigid plates or slats as the material transfer medium [8]. These slats are typically made from durable materials such as metal or reinforced plastic and are attached to a moving chain to transport items automatically [9]. This type of conveyor is specifically designed to handle heavy, large, or irregularly shaped items that are difficult to manage with other types of conveyors, such as belt conveyors [10].

Several studies have been conducted related to the modeling of an automated slat conveyor system based on PLC [11]. One study focused on the design and optimization of a slat conveyor system for tractor assembly, including all design calculations such as power calculation, chain selection, sprocket selection, shaft design, etc. Another study aimed to create a conveyor trainer with an outseal PLC as an instructional tool [3]. Other research developed an automatic packaging system using a PLC, which previously operated manually, resulting in improved production output [4], [12]. Additionally, a study on the integration and programming of systems using Mitsubishi PLC demonstrated effective performance in controlling prototypes, such as improving timing accuracy.

Automation systems using conveyors with PLCs as controllers have been widely implemented in industrial settings. The slat conveyor modeling for the vehicle quality inspection process in this study is based on previous research and is further developed for application in optimizing vehicle quality checks in manufacturing industries. The improvement through this automation system is part of the Kaizen approach, which aims to continuously enhance production efficiency. Kaizen, a Japanese term, refers to the process of ongoing improvement.

In vehicle quality inspection processes, where vehicles are traditionally moved manually between inspection stations by drivers, significant inefficiencies arise. This study proposes utilizing a slat conveyor system controlled by a programmable logic controller (PLC) to optimize the inspection process. By automating the transfer of vehicles between inspection stations, inspections can be conducted concurrently with the conveyor's movement, significantly improving efficiency and reducing manual intervention.

2. METHOD

Figure 1 illustrates the block diagram of the slat conveyor automation system, which consists of several input and output components. The three main inputs in this system are the photoelectric sensor, push button, and selector switch. The photoelectric sensor is responsible for detecting objects passing over the conveyor, sending signals to the control system to indicate the presence of an object that needs to be moved. The push button is used for manual operation commands, such as turning the conveyor on or off, while the selector switch allows the user to choose specific operational modes, such as adjusting the speed or direction of the conveyor's movement. The Programmable Logic Controller (PLC) serves as the main controller, receiving signals from the inputs and processing them to control the appropriate outputs. The outputs of the system consist of the DC motor, which is used to drive the slat conveyor, and a lamp as a status indicator. The PLC controls the DC motor to ensure the conveyor operates as needed and activates the lamp to show the operational status of the system. Therefore, this system allows for the automated operation of the slat conveyor with efficient control through the PLC, sensors, and manual controls.

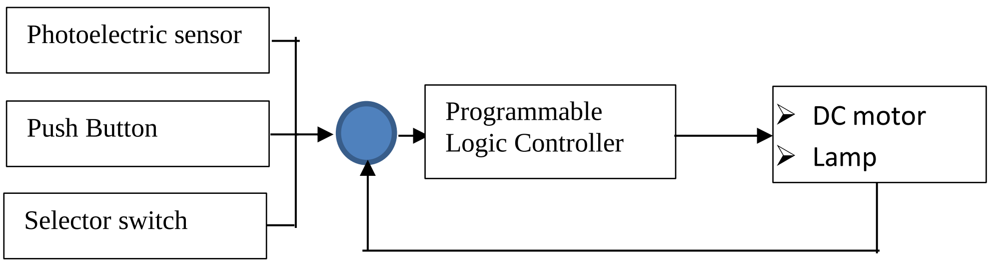

Figure 1. Block diagram of automation system

The conveyor system modeling uses a Programmable Logic Controller (PLC) to automate the operation of the conveyor. The panel interface acts as a bridge between humans and machines, allowing operators to control and monitor the conveyor system. This panel enables users to turn the system on or off, providing flexibility in operation. Additionally, the photo sensor is used to detect objects passing through the conveyor. When an object is detected, this sensor activates the automation process, allowing the system to operate without manual intervention. If there is any anomaly in the process, the conveyor push button serves as an emergency stop button to quickly halt the system, preventing further damage or accidents.

Regarding the outputs, two main components are controlled based on the inputs received by the PLC: the DC motor, which serves as the primary driver of the conveyor to move goods, and the LED, which functions as a status indicator to inform the operator of the system's condition or the process being carried out. Thus, this conveyor system combines automatic control via PLC, sensors, and manual control to ensure efficient and safe operation.

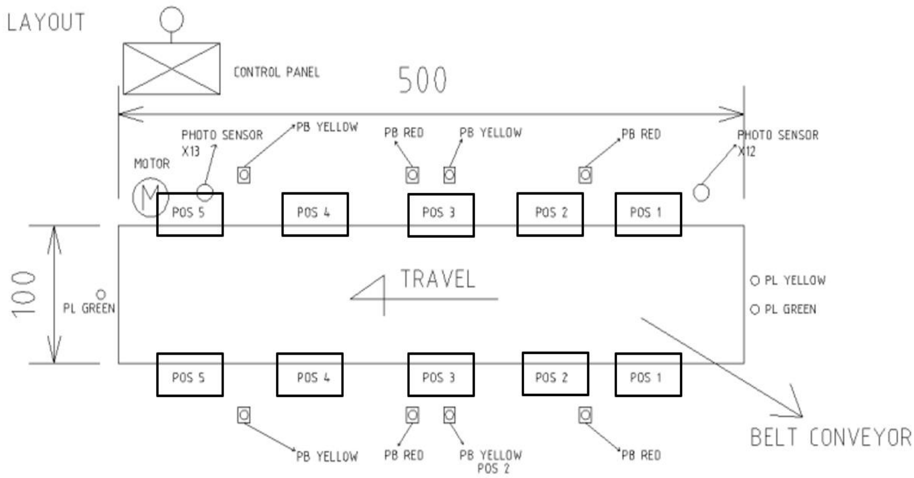

Figure 2. Slat conveyor system layout.

The modeling of this slat conveyor is designed to enhance efficiency and safety in the transportation process of vehicles. The system is equipped with two photoelectric sensors, placed at the vehicle's entry and exit points. These sensors are responsible for detecting the presence of the vehicle as it enters or exits the conveyor area, allowing the system to automatically control the conveyor's movement based on the vehicle's position. Additionally, there is a motor with a potentiometer used to drive the conveyor. The potentiometer is used to control the motor's speed, enabling precise adjustments to the conveyor's operational needs. This allows for flexibility in system operation, whether slowing down or speeding up the conveyor movement according to on-site conditions.

To improve safety and prevent damage to the system, there are several emergency stop buttons that allow the operator to halt the conveyor's operation in the event of an abnormal condition or disturbance in the process. These buttons provide manual control to the operator to immediately stop the system when necessary, reducing the risk of further damage or accidents. Overall, this slat conveyor model integrates various components to create an efficient and safe automated system, with monitoring and manual controls to handle any undesirable situations.

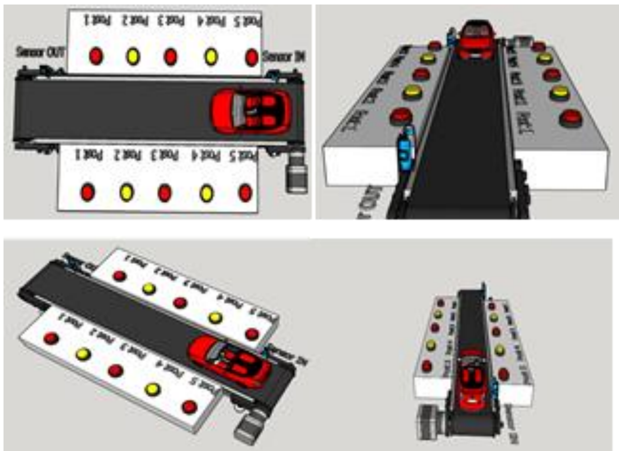

Figure 3. Mechanical design

3. RESULTS AND DISCUSSIONS

The result of the slat conveyor automation design is a culmination of all the processes outlined in the previous chapters. This research aims to design and model an automated slat conveyor system based on a PLC, where all the selected and designed components, such as sensors, motors, controllers, and emergency buttons, are integrated into one cohesive system.

After the design and testing stages, the results of this research demonstrate how these components work together within a single system to automate the movement of goods or vehicles along the conveyor. This system is modeled based on the use of a Programmable Logic Controller (PLC) as the main control unit that manages the entire process, from object detection using sensors to the conveyor's movement through the motor, as well as manual control via emergency buttons.

Thus, the result of this design not only includes theoretical concepts and calculations but also practical implementation of a system that can operate automatically and safely. The modeling performed will show how this automation system can enhance efficiency, reduce human intervention in conveyor operations, and ensure the system operates smoothly while handling abnormal conditions effectively.

Figure 4. Design results

The first step in the testing process is to check the voltage entering the electrical devices. This is done to ensure that the voltage supplied to the equipment is neither too high nor too low, preventing potential damage or failure to operate. If the voltage is too high, it could cause components to burn out or be damaged, while insufficient voltage may lead to malfunction or failure to power the device. During this phase, measurements of the primary source and outputs from the AVR (Automatic Voltage Regulator) are taken. These include the Output AVR 220/12 VDC, which provides 12V DC from a 220V AC source, typically used for devices requiring low voltage, and the Output AVR 220/24 VDC, which delivers 24V DC from the same 220V AC source, suitable for devices that need higher power or have components designed for higher voltage. This verification ensures that the devices receive the correct voltage for safe and optimal operation.

Table 1. Voltage measurement results

Voltage (V)	Results
Primary voltage	213.3V AC
power supply output 01	12.12V DC
power supply output 02	25.63V DC

This description details the dimensions of a conveyor system, providing an overview of the size and proportions of the different parts involved in the material handling process. The length of the conveyor is 480 mm, which represents the main area where items or materials are transported. The width of the conveyor is 100 mm, indicating the width of the main transport path. The width of the left deck is 48 mm and the width of the right deck is 48 mm, referring to the side structures of the conveyor that may be used for supporting elements or other components on either side. The width of the exit deck area is 50 mm and the width of the entrance deck area is 50 mm, representing the dimensions of the areas where materials enter or exit the conveyor, which may also house sensors or control mechanisms. The overall width of the conveyor is 210 mm, which includes the main conveyor and the side decks. Finally, the overall length of the conveyor is 600 mm, encompassing the main transport area and all additional sections such as decks and entry/exit zones. These dimensions provide a complete picture of the physical size of the conveyor system, designed to efficiently move materials while ensuring safe operation and proper configuration.

Table 2. Results of conveyor modeling dimensional measurements

Conveyor Parts	Dimension
Length of the conveyor	480 mm
Width of the conveyor	100 mm
Width of the left deck	48 mm
width of the right deck	48 mm
width of the exit deck area	50 mm
width of the entrance deck area	50 mm
overall width of the conveyor	210 mm
overall length of the conveyor	600 mm

Table 3 shows the results of testing the photo sensor against object distance. The ideal distance between the photo sensor and the object is between 70 mm and 160 mm: This is the range where the photo sensor works optimally in detecting objects. Within this range, the sensor can detect objects with high accuracy, providing a stable signal. For object distances between 15 mm and 60 mm, the sensor still detects the object and provides an ON signal. This means that even though the object is closer than the ideal range, the sensor can still detect it and indicate the presence of the object. At a distance of 80 mm, the sensor continues to detect the object and provides an ON signal, even though it is outside the ideal range (70 mm - 160 mm). This indicates that the sensor can still function even when the object is slightly outside the recommended distance. However, if the object is further than 170 mm, it is no longer detected by the sensor, and the input signal becomes OFF, indicating that the sensor cannot detect the object at that distance.

Tabel 3. Object distance detection test results

Object distance (mm)	Signal input
15-60	On
80	On
120	On
160	On
170	On
205	Off
300	Off
330	Off

The testing conducted aimed to measure the travel time and speed of the conveyor at different input voltages. The results showed that as the input voltage increased, both the travel time and speed of the conveyor improved. With a 1.25 V input, the travel time was 12.5 seconds, and the speed was 0.038 m/s, indicating slower movement. At 3 V, the travel time decreased to 3.6 seconds, and the speed increased to 0.13 m/s, demonstrating a faster conveyor. With 6 V, the travel time further reduced to 1.6 seconds, and the speed increased to 0.3 m/s, showing a significant improvement in speed. At 9 V, the travel time dropped to 1.2 seconds, and the speed rose to 0.4 m/s. Finally, with the highest input of 11.97 V, the travel time was reduced to 0.8 seconds, and the speed reached 0.6 m/s, the fastest observed. These results indicate that higher input voltages lead to faster conveyor speeds and shorter travel times, illustrating the direct relationship between voltage and conveyor performance.

Table 4. Time response measurement results

Voltage input(V)	Time (s)	Speed(m/s)
1.25	12.5	0.038
3	3.6	0.13
6	1.6	0.3
9	1.2	0.4
11.97	0.8	0.6

4. CONCLUSION

In conclusion, the automated slat conveyor system designed and modeled in this research successfully integrates multiple components, including sensors, motors, and a Programmable Logic Controller (PLC), to automate the movement of materials or vehicles along the conveyor. The system was developed to enhance efficiency, reduce human intervention, and ensure safe operation, even in abnormal conditions. The results from the voltage testing phase confirmed that appropriate voltage levels are crucial for optimal performance, preventing damage to the system. The conveyor's design was thoroughly tested, with results indicating that higher input voltages lead to increased speed and reduced travel times, thus optimizing the conveyor's performance. The photo sensor testing demonstrated the ideal operating distance range, ensuring reliable object detection and stable signals. Overall, this research validates the effectiveness of the PLC-based automation system, showing its potential for improving material handling in various industrial applications, offering both theoretical insights and practical implementation strategies.

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