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Design of Control System for Pusher Plate Automatic Loading and Unloading Machine

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Abstract: Aiming at the problem that the automatic loading and unloading system of the lathe is controlled by the electric control, which leads to the aging of the coil and the complicated wiring, this paper designs a control system that can automatically load and unload the material to meet the requirements of high efficiency automatic processing, stability and reliability of the lathe. This system uses Delta PLC as the controller and touch screen control to realize the automatic transmission from the loading machine to the lathe for processing, and then from the lathe to the blanking machine after processing. Equipped with pneumatic system, it can quickly and reliably realize the push and discharge actions. The system can be used in production, reduce the time of loading and unloading, and improve production efficiency.

Keywords: Loading and unloading machine, Control system, PLC.

1. Introduction

With the arrival of the new era of intelligent manufacturing and the significant development of artificial intelligence, smaller factories are undergoing transformations and upgrades to become automated factories in order to enhance production efficiency [1]. As a result, the application of automated processing equipment is becoming increasingly widespread.

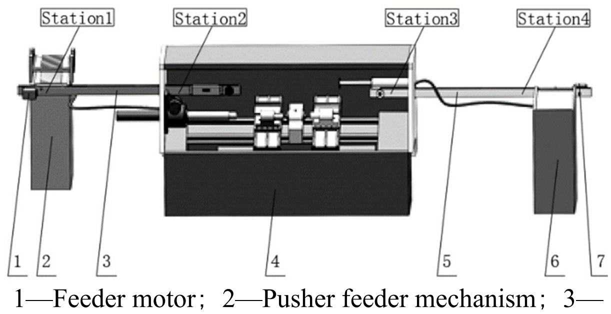
Currently, the push-pull type loading and unloading machine used in the CNC workshop of our company is controlled by electrical circuits. However, the circuit stability is not reliable. For example, the relays, which actuate the executive components when energized through their coils, can experience aging issues over time [2-3]. Ultimately, this can affect the control circuit.

Sometimes, when there is a need for minor changes, additional electrical components such as relays and wiring are required, and at times, an additional control cabinet needs to be considered due to severe space constraints. Due to production requirements, it is necessary to set parameters and display certain signals, which cannot be achieved through the electrical control circuit alone.

In order to ensure reliable control of the system and considering the reliability and maintainability of the control system, a highly automated loading and unloading equipment has been designed [4-6]. This push-pull type automated system is based on PLC (Programmable Logic Controller) control, offering faster loading and unloading speeds, thereby enhancing production efficiency. It holds significant value for widespread application [7].

2. Overall System Design

As shown in Figure 1, the push-pull type automatic loading and unloading mechanism is a critical component of the automated CNC machine tool, aiming to achieve automation on the production line [8]. The push-pull type automatic loading and unloading mechanism consists of three parts: the push-pull loading mechanism, the loading and unloading motor, the conveyor belt, and the unloading pushing mechanism. The workflow of the push-pull type automatic loading and unloading mechanism is as follows: The operator initially places the bar workpieces into the loading mechanism, with a maximum of 50 pieces at a time. After completing all necessary checks, the operator activates the power supply. At this point, the feeding cylinder of the loading mechanism pushes the bar materials to station 1. Upon receiving the signal from the sensor at station 1, the loading motor drives the conveyor belt, which stops rotating when the bar material reaches station 2. This loading process continues in a cyclic manner. Once the bar material is processed on the CNC lathe, the sensor at station 3 detects its presence. Subsequently, the unloading motor drives the conveyor belt, delivering the processed bar material to station 4. After a 5-second delay, the blocking cylinder automatically retracts, allowing the processed bar material to slide into the unloading bin.



1—Feeder motor; 2—Pusher feeder mechanism; 3—Conveyor belt 1; 4—CNC lathe; 5—Conveyor belt 2; 6—Unloading pusher mechanism; 7—Unloading motor

Figure 1. Pusher-type Loading and Unloading Mechanism.

3. Hardware Design of The Control

SystemDue to the high reliability, strong anti-interference capability, and low cost of use, the Delta PLC is selected [9-10]. The programmable controller chosen is the DVP32ES200T model. It has 16 digital inputs and 16 digital outputs, with NPN-type outputs and a maximum passing current of 0.5A. The power supply connected is AC. For the

HMI (Human Machine Interface), the Kunlun Tongtai touchscreen with a 7-inch display, model TPC7032kt, is chosen. It offers powerful functionality, easy programming, an attractive appearance, and high touch sensitivity.

The electrical control system architecture, as shown in Figure 2, is the equipment for human-machine interaction. The touchscreen functions to set, control, and debug relevant parameters. It communicates with the PLC via an Ethernet cable, with the touchscreen and PLC having the same IP address in the network segment. The PLC's IP address should be set as the gateway. Once the settings are completed, instructions are sent to the PLC, and the information returned by the PLC is displayed in real-time [11-12].

The PLC acts as the controller, similar to the brain of the control system. Its crucial functions include signal and data acquisition and management, control of the stepper motor, control of the cylinder, and control of indicator lights [13]. Since the PLC's outputs are transistor type with low current, intermediate relays are used to connect to the actuators. When the PLC receives signals from sensors or buttons, it outputs control signals to the intermediate relays, which then control the solenoid valves and subsequently control the cylinders. The lathe sends alarm signals to the PLC, and the PLC's loading and unloading alarm signals are also transmitted to the lathe via intermediate relays. The PLC controls the stepper driver through pulses and direction signals, ultimately controlling the rotation of the stepper motor and the movement of the conveyor belt. Table 1: Input/Output Address Allocation Table.

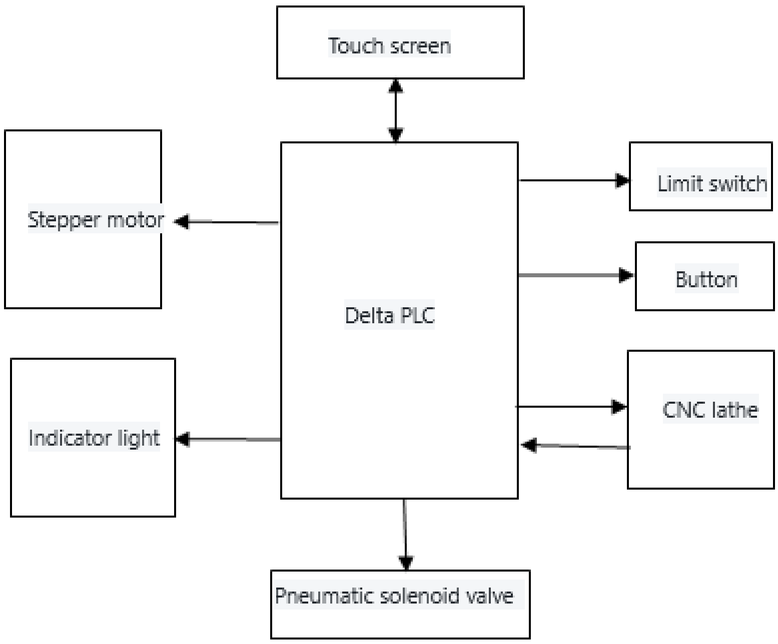


Figure 2. Control System Structure.

Table 1. Input/Output Address Allocation Table.

input side	signal source	output side	signal source
X0	start button	Y0	pulse signal for the feeder's stepper motor
X1	stop button	Y1	direction signal for stepper motor of the feeder
X2	emergency stop button	Y2	pulse signal for stepper motor of the unloader
X3	preparation signal from machine tool to feeder	Y3	direction signal for stepper motor of the unloader
X4	preparation signal from machine tool to unloader	Y4	alarm signal from the feeder
X10	waiting station detection	Y5	alarm signal from the unloader
X11	loading station detection	Y6	feeder cylinder extends
X12	discharging station detection	Y7	unloader cylinder extends
X13	unloading station detection	Y10	start indicator light
		Y11	stop indicator light
		Y13	feeder cylinder retracts
		Y14	unloader cylinder retracts

4. Design of Pneumatic Control System

The pusher-type automatic loading and unloading machine is commonly used in factories, especially in environments with high dust and strong magnetic fields. Considering safety, reliability, and the need for rapid pneumatic actions, an air pressure control system is employed. The pneumatic control system of the pusher-type automatic loading and unloading machine is illustrated in Figure 3. Magnetic switches are used to detect the proximity of the bar stock and transmit the detection signals to the PLC [14].All cylinders in the system are pneumatically controlled. When the bar stock approaches the magnetic switches mounted on the cylinders and the loading/unloading device, the detected signals are promptly sent to the PLC in the control cabinet. Upon receiving the information, the PLC commands the solenoid valves installed on the valve manifold to change the cylinder's direction. The blowing valve is a two-way three-position valve connected to the pneumatic nozzle located adjacent to the CNC lathe's outer side. When the two-way three-position solenoid valve is energized, the pneumatic nozzle blows air to clean the waste generated by the bar stock during production. When the power to the two-way three-position solenoid valve is cut off, the blowing operation stops. To ensure that the cylinders immediately stop their actions when power is cut off, three-way four-port valves are chosen for the solenoid valves.

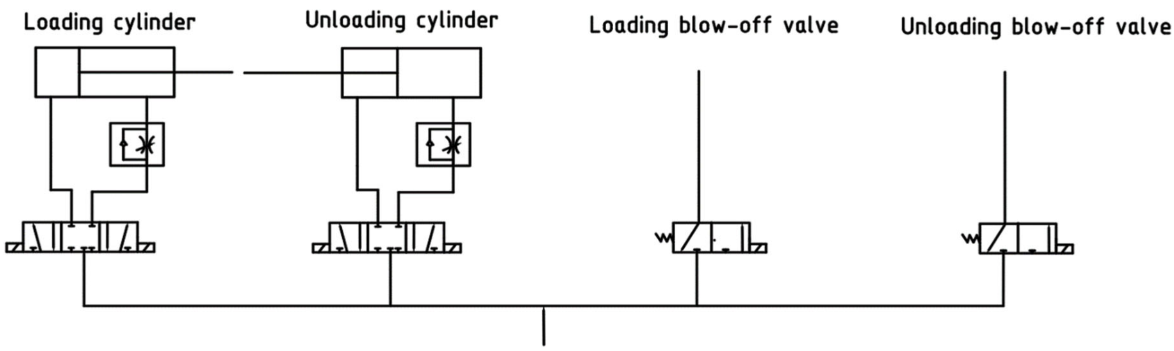


Figure 3. Pneumatic Control System.

5. Software Design of The Control System

5.1. Touch screen interface design

In order to interact with the PLC and control its functions, a touchscreen is used for parameter settings and displaying certain signals. The touchscreen interface design includes the main interface, debugging interface, parameter setting interface, and sensor display, allowing various functions of the loading and unloading system to be implemented. The main interface, as shown in Figure 4, displays the "Working Status" indicating whether the loading and unloading machine is running. The "Current Loading Count" displays the total number of materials transported since the machine was turned on. There is a reset button to reset the "Current Loading Count" to zero. When a fault occurs in the loading and unloading machine, the alarm label changes to red.

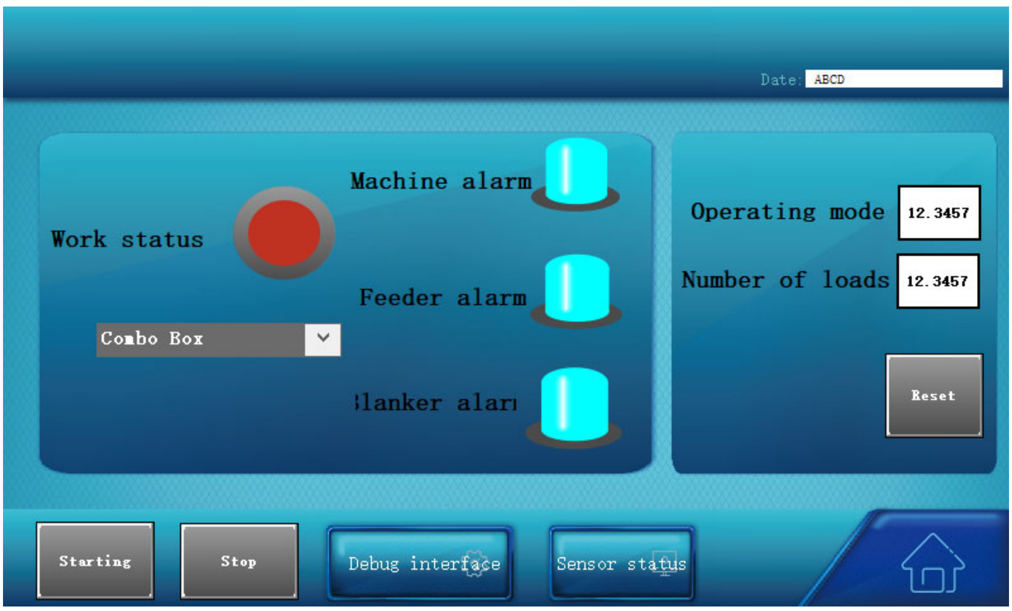


Figure 4. Main Interface.

During the design process, many factors need to be taken into consideration, such as the interlocking functionality between manual operation and automatic operation [15]. The debugging interface is shown in Figure 5, where you can click the corresponding buttons to activate the respective actions.

Figure 5. Debugging Interface.

By utilizing the touchscreen's numerical input functionality, operators can input desired parameters in the parameter setting interface. At this point, a keyboard will pop up on the touchscreen interface for the operator to use [16]. The motor speed setting interface for the feeding motor is shown in Figure 6, allowing the adjustment of the conveyor belt speed by debugging the feeding motor speed.

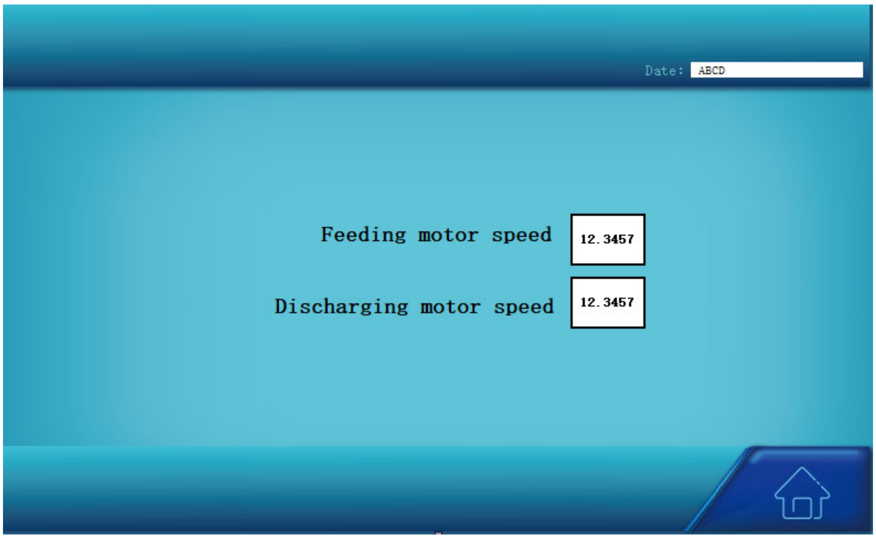


Figure 6. Parameter Setting Interface.

5.2. Program design of the control system

This pusher-type automatic loading and unloading equipment adopts two working modes: automatic mode and manual mode. The control of the working mode is selected through a combo box option on the main interface. In the automatic mode, which is the normal operating mode of the pusher-type automatic loading and unloading equipment, when the bar stock is at the starting position of the machine, the start button is pressed, and the bar stock starts to move immediately. When the position detection proximity switch sends a signal to the PLC, the PLC controls the electromagnetic directional valves to achieve the complete loading process [17]. The working process of the pusher-type automatic loading and unloading equipment in automatic mode is as follows: the loading cylinder extends → the loading cylinder reaches the top position (5s delay) → the loading cylinder retracts → the conveyor belt runs (motor rotates clockwise) → the motor stops; after the bar stock is processed by the machine, the conveyor belt runs (motor rotates counterclockwise) → the motor stops → the unloading cylinder extends → the unloading cylinder reaches the top position (5s delay) → the unloading cylinder retracts. The pusher-type automatic loading and unloading machine completes one work cycle, and then repeats the above actions. Below is the program diagram for automatic operation. Figure 7 shows the start and stop program.

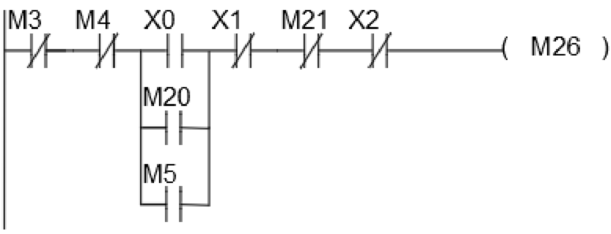


Figure 7. Start and Stop Program.

When using the manual debugging mode, as shown in Figure 8, manual adjustment is generally used for the inspection and maintenance of the pusher-type automatic loading and unloading machine. In the debugging interface, the loading cylinder is controlled by the start button and stop button of the loading cylinder. Similarly, the feeding motor is controlled using the start button and stop button of the feeding motor. By selecting the manual debugging mode through the combo box option on the main interface, the system automatically enters the debugging interface.

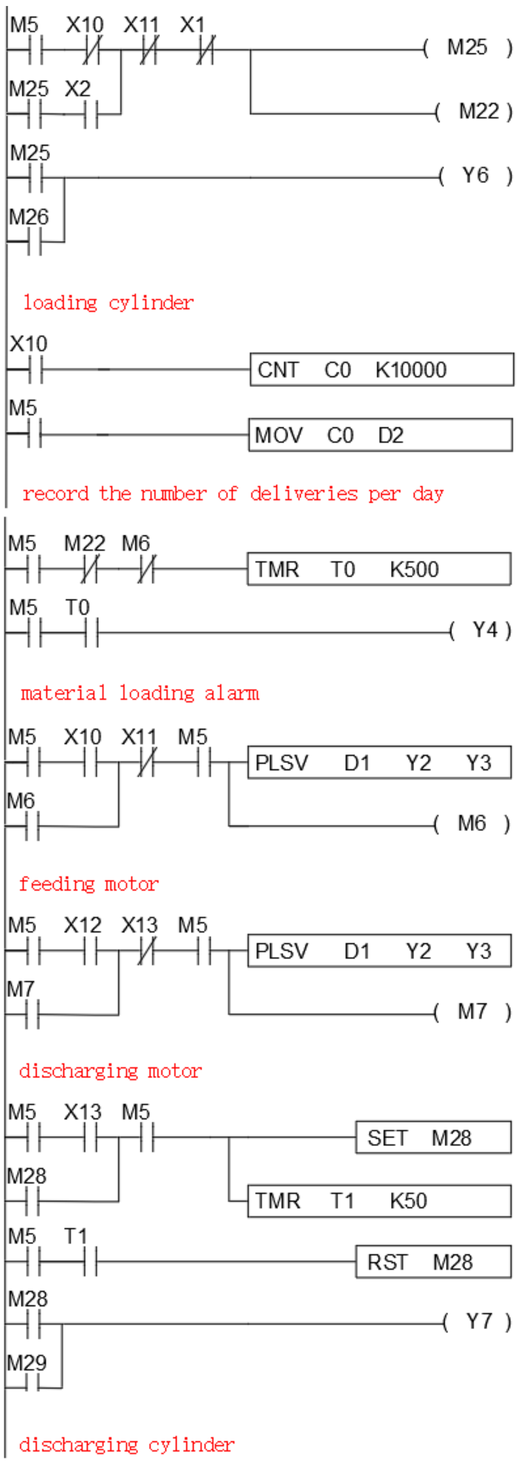


Figure 8. Automatic running program.

When using the inching mode, as shown in Figure 9, for example, when the loading cylinder is running, and the manual debugging mode is selected, the input terminal M40 is connected to initiate the action of the loading cylinder. When the stop button of the loading cylinder is pressed, the input point M41 is connected to stop the operation of the loading cylinder. The control for other components follows a similar process. The design of the manual adjustment control program is relatively simple. The ladder diagram for manual debugging is shown in Figure 4

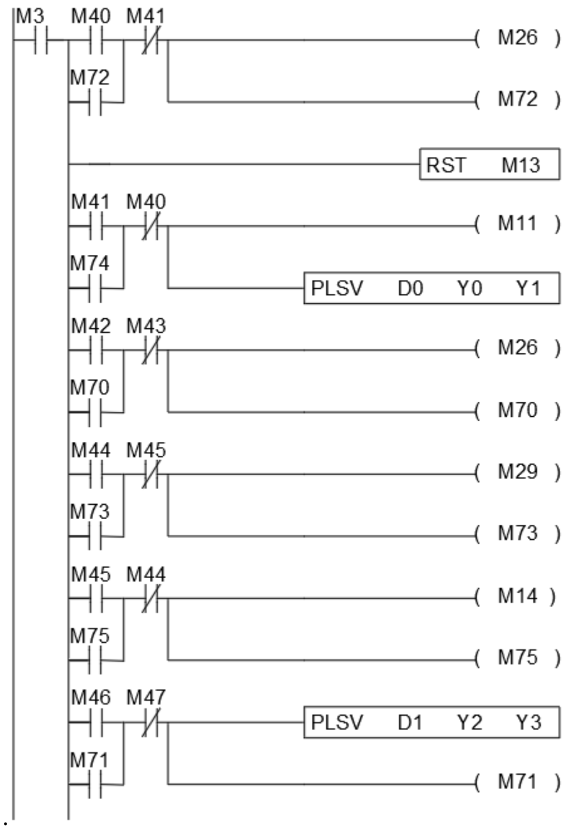


Figure 9. Manual Operation Program.

The manual control program and the automatic operation control program of the pusher-type automatic loading and unloading machine are isolated from each other. Therefore, a conditional jump is used to execute the corresponding control program. If the input terminal M3 is disconnected, the system will choose the manual adjustment mode and execute the automatic operation program section. On the other hand, if M3 is connected, the system will select the manual adjustment program mode and execute the manual adjustment program, skipping the automatic operation section.

6. System Application Effect

After comparing the production before and after the modification, it was found that with normal employee working hours of 8 hours per day, the original production had a scrap rate of 5% caused by operator errors, a total loading and unloading time of 41 seconds, and 5 to 10 equipment failures. However, after the modification, the employee working hours were increased to 24 hours per day, the scrap rate was reduced to 1%, the total loading and unloading time was reduced to 20 seconds, and there were no equipment failures. After three weeks of continuous debugging and testing in the factory, the data shown in Chart 2 was obtained. The main advantages of this loading and unloading equipment system are the replacement of electrical controls. Using a PLC as the control system reduces labor costs, allows for increased working hours, and has an extremely low failure rate with no failures observed during testing.Figure 10: Physical Diagram of Up/Down Feeding Machine.

Table 2. Machining Data Before and After Modification (Three Weeks).

Category	Unit	Production before renovation	Production after renovation
Total loading and unloading time	s	41	20
Actual working time	h	10	24
Defect rate	%	5	1
Number of breakdowns	times	5~10	none

Figure 10. Physical Diagram of Up/Down Feeding Machine

7. Conclusion

In summary, this article has designed a control system for loading and unloading specifically for lathes based on the requirements of equipping lathes with automatic loading and unloading systems. The control system is developed and researched based on the deficiencies of the loading and unloading machine. The system is PLC-based and achieves functions such as rapid automatic loading and unloading, and conveying control for the machine tool. Through practical operation in the factory, the system is capable of continuous and uninterrupted processing of 50 bars of material each time, demonstrating stable performance. This system can be applied in production to reduce labor costs and improve production efficiency. Additionally, it provides useful technology and experience for the research on control systems related to loading and unloading robotic arms in the mechanical industry.

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