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Building an automated product processing model

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ABSTRACT: In the era of globalization and rapid advancements in science and technology, the manufacturing industry is experiencing significant transformations. Automation has emerged as a key driver in improving productivity, product quality, and overall competitiveness. Among various technological solutions, automated workpiece machining systems have been widely adopted to modernize production lines. These systems not only minimize dependence on manual labor but also ensure consistency and precision in manufacturing processes.
The integration of automation technologies provides numerous benefits, including cost optimization, enhanced accuracy, and reduction of human errors. However, their implementation poses several challenges, such as high initial investment costs, stringent technical requirements, and the need for robust management systems [1,2].
To contribute to the advancement of automation technology in Vietnam, this study proposes the development of an automated drilling and boring system for workpieces, controlled by a Siemens S7-1200 Programmable Logic Controller (PLC). The research aims to evaluate both technical and economic aspects, covering technology selection, system design, installation, and operational procedures.
KEYWORDS: Automation, S7-1200, PLC, Product.

I. INTRODUCTION

Automated workpiece machining systems represent a critical component in modern industrial manufacturing processes. Designed to enhance efficiency, precision, and consistency, these systems are increasingly applied across various industries such as machinery manufacturing, automotive, electronics, and consumer goods [2,3].

For a PLC programmer, the first essential task is to interpret and analyze the technological requirements of the problem. In this specific model of automated workpiece feeding and machining, the primary objective is to fully automate the process of loading and machining the workpieces [4,5,6].

Based on the technological schematic of the system, the sequence of operations can be described as follows:
- First, the raw workpiece is introduced into the feeding system.
- The workpiece is then transferred to a storage chute via a guiding rail system and a rotating disc located in the feeder unit.
- Next, a pneumatic cylinder-driven gripper arm picks the workpiece from the chute and positions it into the chuck.
- At this point, the tool carriage advances to perform the cutting operation.
- Upon completion, the gripper retrieves the finished product and removes it from the machining area.

This structured sequence ensures a continuous, automated cycle with minimal human intervention while maintaining high precision and repeatability in the machining process.

II. DESIGN MODEL PROPOSAL

2.1. System structure

System Design Requirements

The automated workpiece machining model is designed to perform drilling and reaming operations on cylindrical wooden workpieces. Each workpiece has a height of 4 cm and a diameter of 3 cm. The drilling operation requires a hole with a depth of 3 cm and a drill bit diameter of 3 mm. The reaming operation is adjustable based on the desired surface roughness, which determines the appropriate spindle speed of the motor during the finishing process.

a. System Dimensions
- Length: 85 cm
- Width: 60 cm
- Height: 35 cm

b. System Components
- Raw Material Feeding System:
- Storage tube and pneumatic pusher: The workpiece is pushed from the storage tube onto the conveyor belt using a pneumatic cylinder.
- Conveyor and Workpiece Transport System.
- Automated conveyors are used to transfer the workpieces from the storage area or loading point to the machining units.

c. Workpiece Specifications (Figure 1)
- Material: Wood
- Dimensions: Diameter 3 cm, Height 4 cm
- Machining Operations: Drilling holes and surface reaming.

The design of the system aims to ensure precise positioning, stable material transfer, and consistent machining performance under fully automated control.

Figure 1. Embryo used in the model

d. Cutting Tool Specifications
- Material: Steel
- Drill Bit Type: Diameter 3 mm, Length 8 cm

Application: Suitable for both drilling and reaming operations on wooden cylindrical workpieces. The tool is selected to ensure high precision and durability under continuous automated operation.

Figure 2. Drill bit used in the model

Figure 3. Boring disc used in the model

e. SCADA (Supervisory Control and Data Acquisition)
- The SCADA system is utilized for centralized monitoring and control of the entire production process. It collects real-time data from sensors and devices across the system, enabling operators to supervise and respond promptly to operational conditions.

f. PLC (Programmable Logic Controller)
- The PLC is responsible for executing automated control tasks, managing signals from sensors and actuators to ensure synchronization, precision, and safe operation throughout the system.

g. HMI (Human-Machine Interface)
- The HMI panel provides an interactive interface for operators to monitor system status, view alarms, and perform manual control when necessary. It serves as the primary interface between the user and the automated process.

2.2. Conceptual Operating Principle of the System

After the system is powered on, Sensor 1 checks for the presence of workpieces in the feed tube. If a workpiece is detected, Cylinder 1 pushes it from the feed tube onto the conveyor. The conveyor then transports the workpiece to the drilling station. When Sensor 2 detects the presence of a workpiece at the drilling position, Cylinders 2 and 3 activate to secure the workpiece. A stepper motor then lowers the drill bit to perform a drilling operation to a depth of approximately 3 cm. Once the drill reaches the designated depth, it triggers a limit switch, indicating the end of the drilling process. The drill bit then retracts to its original position until it contacts the return limit switch, at which point the motor stops. After the drilling operation is completed, Cylinders 2 and 3 release the workpiece, allowing the conveyor to move it to the next station.

At the reaming station, if Sensor 3 detects the incoming workpiece, Cylinders 4 and 5 activate to hold it in place. A second stepper motor, connected to a lead screw mechanism, lowers the reaming tool onto the workpiece. Once the reaming head reaches the designated depth and activates a limit switch, the reaming process is considered complete. The motor then returns the reaming tool to its original position, stopping when it contacts the upper limit switch. At the same time, Cylinders 4 and 5 release the workpiece, which continues to move along the conveyor.

After passing through both the drilling and reaming processes, the finished workpiece is conveyed to a storage box located at the end of the conveyor.

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III. BUILDING A MODEL OF AUTOMATIC BOWL PROCESSING SYSTEM

3.1. Building physical models

a. Mechanical drawings

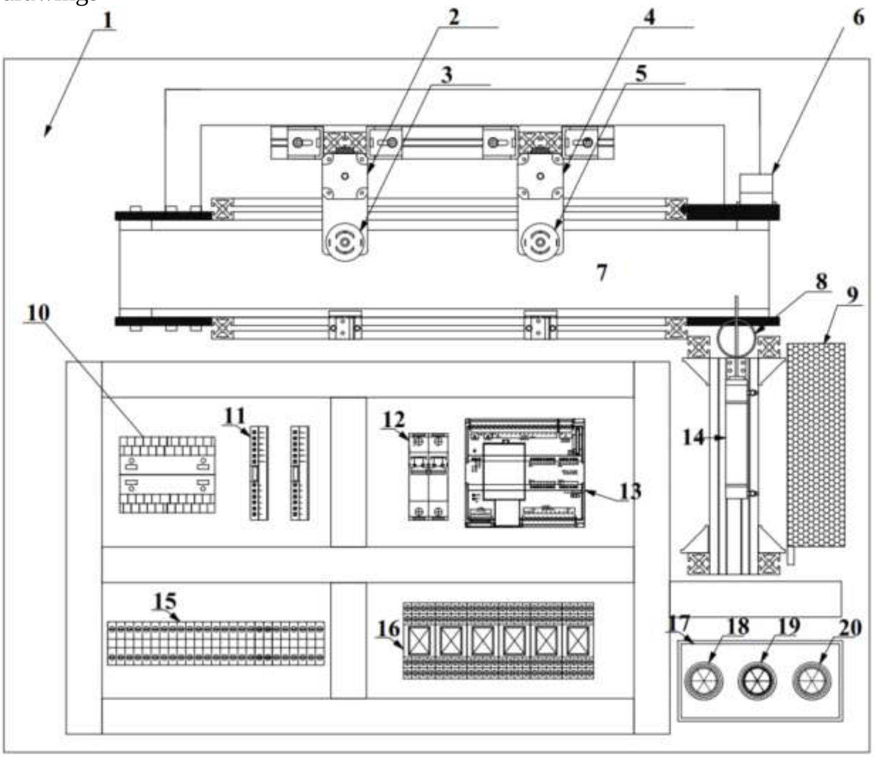

Figure 4. Overview drawing of the model

Table 1. Equipment used

No.	Component	Description
1	Equipment Base Frame	Structural support platform for mounting all mechanical and electrical parts.
2	Stepper Motor 1	Controls vertical movement of the drilling mechanism.
3	Reaming Motor	Drives the reaming tool for surface finishing.
4	Stepper Motor 2	Controls vertical movement of the reaming mechanism.
5	Drilling Motor	Drives the drill bit for machining holes into the workpiece.
6	Conveyor Motor	Powers the conveyor belt for workpiece transportation.
7	Conveyor Belt	Transfers workpieces between stations during the machining process.
8	Feed Tube	Holds raw workpieces before being pushed onto the conveyor.
9	24VDC Power Supply	Provides DC power for control system components.
10	Common Terminal Block	Electrical distribution and grounding terminal for system wiring.
11	Stepper Motor Driver	Controls stepper motors' direction and speed via signals from the PLC.
12	Circuit Breaker (MCB)	Protects electrical circuits from overloads and short circuits.
13	Siemens S7-1200 PLC	Central controller for automation logic and device coordination.
14	Workpiece Feed Cylinder	Pneumatic cylinder that pushes workpieces from the feed tube onto the conveyor.
15	UK5N Terminal Block	Used for safe and modular wiring connections.
16	Intermediate Relay	Isolates and amplifies control signals between PLC and actuators.
17	Start Button	Manual control to initiate system operation.
18	Stop Button	Manual control to halt system operation.
19	Warning Buzzer	Provides audible alerts for errors or important system statuses.

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b. Electrical drawings

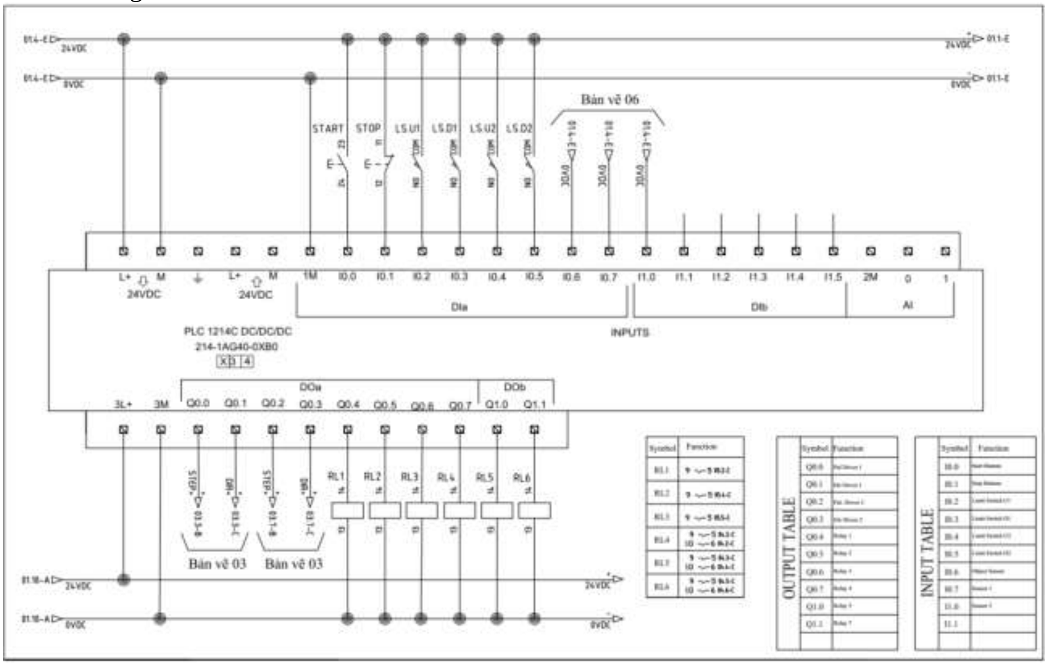

Figure 5. PLC drawing

Table 2. PLC input definition table

Function	Address
Start Button	I0.0
Stop Button	I0.1
Limit Switch 1	I0.2
Limit Switch 2	I0.3
Limit Switch 3	I0.4
Limit Switch 4	I0.5
Object sensor	I0.6
Drill sensor	I0.7
Boring sensor	I1.0

Table 3. PLC output definition table

Function	Address
Pul 1	Q0.0
Dir 1	Q0.1
Pul 2	Q0.2
Dir 2	Q0.3
Relay 1	Q0.4
Relay 2	Q0.5
Relay 3	Q0.6
Relay 4	Q0.7
Relay 5	Q1.0
Relay 6	Q1.1

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3.2. Build control program for model

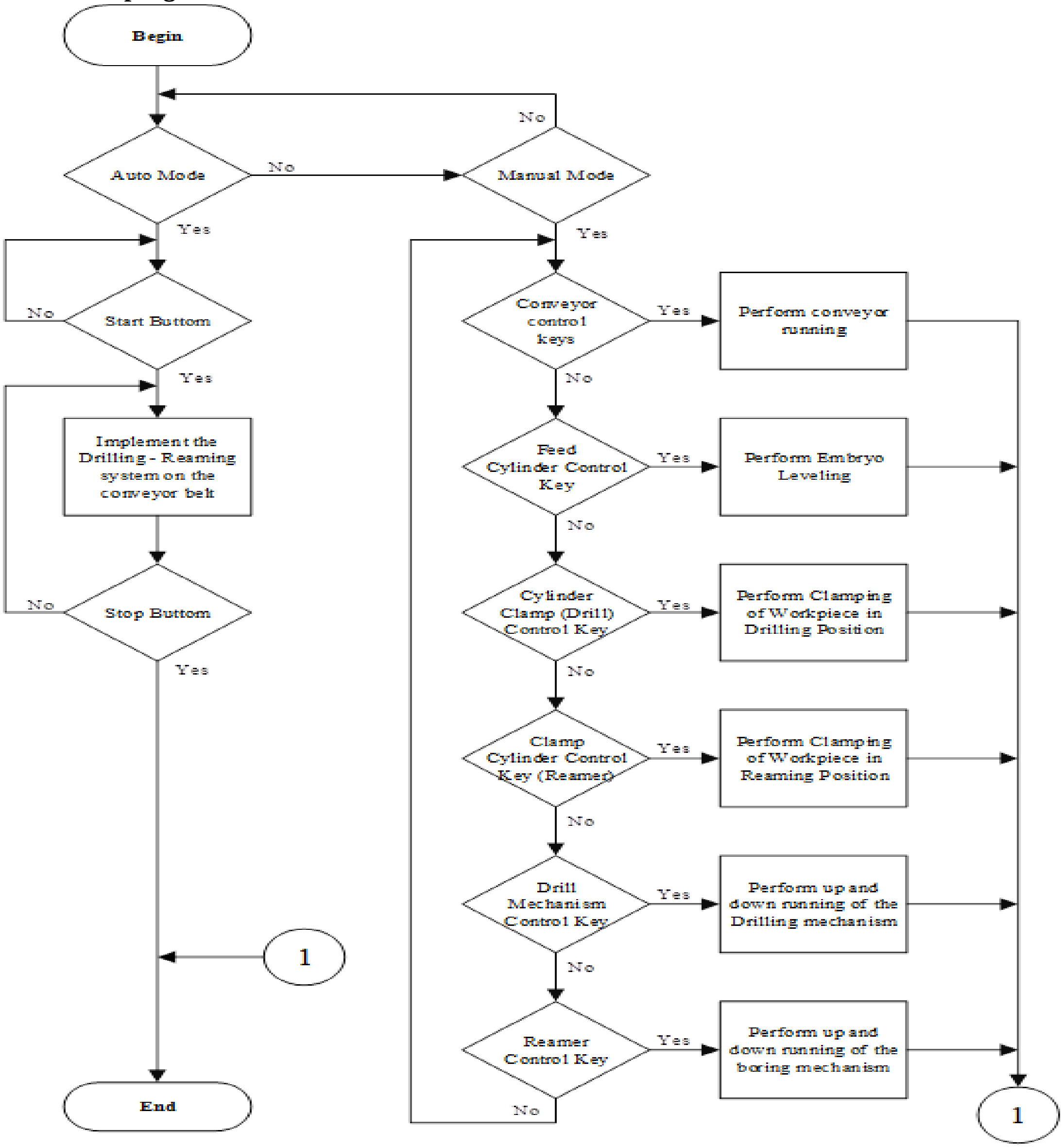

Figure 6. Algorithm flowchart for the system

When starting the system, select either Automatic Mode or Manual Mode. If Automatic Mode is selected incorrectly, the system checks Manual Mode, and vice versa. (Figure 6)

Manual Mode:
1. Press the conveyor control button → if correct, the conveyor runs.
2. If incorrect, check the feed control button → if correct, activate the clamping cylinder (drilling position).
3. If correct, the workpiece is clamped in drilling position → if not, check the clamping control button for the reaming station.
4. If correct, clamp at reaming position → if not, check the drilling mechanism control button.
5. If correct, the drilling mechanism operates → if not, check the reaming mechanism.
6. If correct, the reaming unit moves up/down → if not, return to conveyor control.
7. If correct, the manual startup cycle is completed.
8. If not, check the conveyor control again.

Automatic Mode: (Figure 7)
Start by pressing the Start button:
1. Drill motor starts → if the limit switch is not triggered, motor returns to standby.
2. Check reaming unit limit switch → if not triggered, motor returns to standby.

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3. If OK, check sensor for workpiece detection → if not detected, return to drill/reaming limit switch check.
4. If detected, the pusher cylinder feeds the workpiece onto the conveyor.
5. Conveyor moves the piece to the drilling station → if sensor does not detect the piece at drill station, check feed cylinder again.
6. If detected, conveyor stops, workpiece pauses for 2 seconds.
7. If misaligned, return to check drill station positioning.
8. If correct, conveyor resumes and workpiece moves to reaming station.
9. Wait ~2 seconds → if sensor fails, check conveyor again.
10. If all OK, workpiece continues.
11. Press Stop → if conveyor continues running, check pusher cylinder again.
12. If all conditions met → process ends.

Drilling Position Handling (Figure 8):
At drilling position:
1. If drill position incorrect → recheck.
2. If correct → clamping cylinder engages.
3. After 1 second, if workpiece is misaligned → recheck.
4. If correct → drill moves downward to perform operation.
5. If current drill position ≠ preset position → drill does not move down.
6. If OK → drill returns to standby and hits limit switch.
7. If not triggered → recheck movement.
8. If OK → drill stops → clamping opens → drilling is complete.

Figure 7. Flowchart of automatic running mode algorithm

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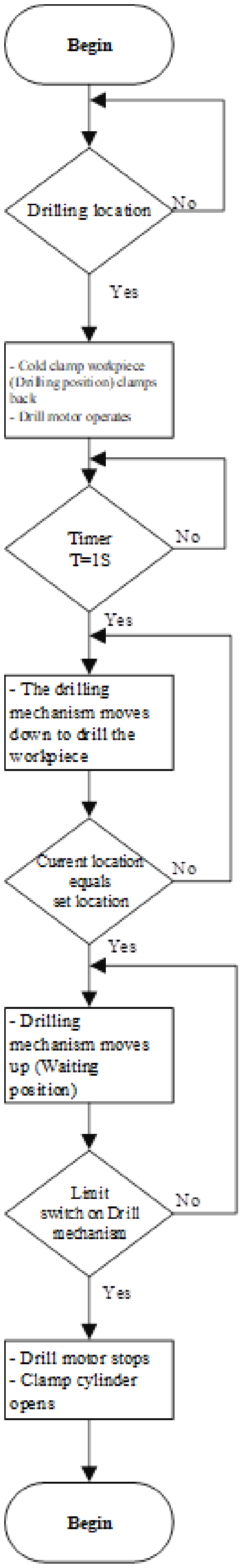

Figure 8. Algorithm flowchart at the drilling position

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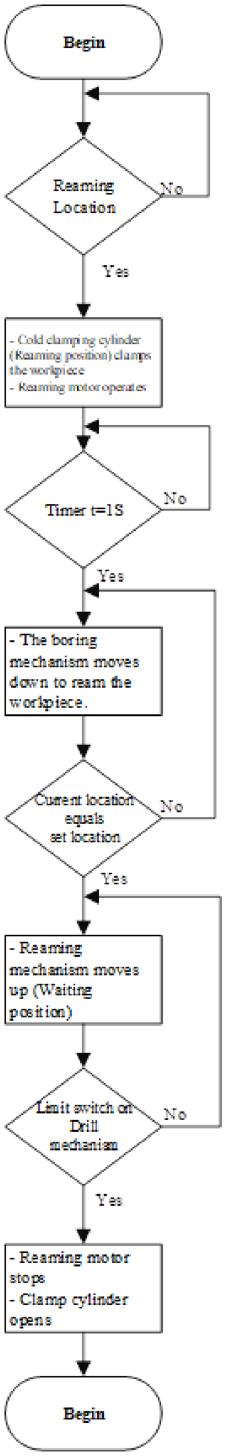

Figure 9. Algorithm flowchart at the position of flattening the workpiece surface

Surface Finishing – Reaming Station (Figure 9):

At the reaming station:
1. Start: If the reaming position is incorrect → recheck position.
2. If correct → the clamping cylinder engages (same clamping unit as drilling station).
3. Wait 1 second.
+ If the workpiece is misaligned → recheck.
+ If correctly positioned → the reaming unit moves downward to begin surface machining.
4. If the current reamer position ≠ preset position, the reaming unit does not move down.

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5. If the position is correct → the reaming unit retracts upward to the standby position and contacts the limit switch.
+ If the switch is not contacted → recheck reaming unit movement.
6. If correct → reaming motor stops, clamping cylinder releases, → reaming process is complete.

3.3. Results Achieved

Figure 10. Model image

The model clearly demonstrates the operating principle and can be used for training or testing before actual deployment in industry

The functional blocks are arranged separately, reasonably, easily observe, convenient for programming and maintenance.

It can be further improved to upgrade to an experimental training model in schools or integrated into small production lines in light industry.

Figure 11. Monitoring image of the model

IV. CONCLUSIONS

The paper has proposed and developed a model for automated product machining. The research team has validated the existing theoretical framework through the evaluation of a physical prototype. In the future, the authors aim to further optimize the system for practical application in industrial production.

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