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Design of a PLC-Based Automatic Flat-Plate Fabric Pressing Machine Model for Educational Purposes

Cuong Nguyen Thai
Faculty of Mechanical and Electrical Engineering, Hanoi Industry and Trade University, Hanoi, Viet Nam

ABSTRACT : *In the context of engineering education at universities aimed at meeting the requirements of the Fourth Industrial Revolution and digital transformation, interdisciplinary research integrating mechanical and electrical engineering in technical training not only contributes to improving the quality of engineering education but also establishes a foundation for students to access and develop scientific research activities in the engineering field. Furthermore, the research outcomes address practical issues such as the limited availability of specialized sewing practice equipment due to high costs, while simultaneously enabling students to access real-world equipment for learning and research purposes. This paper presents the design and fabrication of a PLC-based automatic flat-plate fabric pressing machine for teaching applications at Hanoi Industry and Trade University.*

Keywords: *PLC, automatic, heat, teaching, design*

INTRODUCTION

In industrial garment production lines, in addition to sewing machines and specialized equipment, there are also auxiliary devices that support the manufacturing and finishing processes. These devices are indispensable and play a crucial role in shaping product appearance and ensuring product quality. Among them, heat press machines are widely used auxiliary devices in the garment industry. Currently, the demand for decorative patterns on products is increasing significantly due to the diversity and continuous evolution of fashion trends. Therefore, within the scope of this study, a heat press machine was selected for design and fabrication research.

The flat heat press machine is one of the most commonly used thermal transfer devices in heat transfer printing technology. It can be applied to a wide range of flat-surfaced products such as plastic, metal, ceramics, and fabrics. There are two main types of flat heat press machines: the clamshell type and the swing-away type. Both configurations consist of upper and lower flat plates for pressing products, where the upper plate serves as the heating element while the lower plate is used to position the product during the pressing process

Fig. 1. Flat Heat Press Machine

The automatic pressing machine is programmed to operate automatically with preset parameters, including temperature, pressing time, and pressing force. The pressing force can be adjusted in advance depending on the thickness and properties of the material. The PLC control system of the automatic flat-plate pressing machine is governed by a central processing unit (CPU), which controls all PLC operations. The processing speed of the CPU directly determines the control speed of the PLC system. The control program is designed to regulate the heating temperature of the pressing plate as well as the pressing duration for the product. The CPU continuously scans the program and executes commands sequentially.As a university specializing in mechatronics education for the textile and garment industry, teaching and research activities related to garment equipment still encounter many difficulties due to the lack of practical models and real industrial systems. Therefore, the research and fabrication of a PLC-based automatic flat-plate fabric pressing machine model for teaching purposes are essential to meet the demands of learning, research, and industrial machine design in general, and garment equipment in particular.

OPERATING PRINCIPLE OF THE HEAT PRESS MACHINE

2.1 Overview of the Automatic Heat Press Machine

The flat-plate press machine operates using two flat pressing plates made of metal or heat-resistant rigid plastic, with a parallel surface tolerance between the two plates of approximately 0.05 mm. Heat press machines are widely and commonly used in factories, garment workshops, and fashion businesses.In general, the structure of a heat press machine consists of several main components, including the machine body, pressing frame, working table, pneumatic system, sliding rails, guide sliders, heating plate, compression force adjustment system, and electronic sensors that allow adjustment of pressing time, temperature, and pressing force. The pressing force is controlled through the pressure supply system from an air compressor tank. In addition, the machine is equipped with a control system, push buttons, and a touch display interface for operation and parameter setting.

Fig.2. Double-Station Heat Press Machine

There are various types of heat press machines available on the market; however, their level of automation remains relatively limited and still heavily depends on operator intervention. Typical examples include manual heat press machines, in which the lower pressing plate is fixed while the upper pressing plate is manually operated by workers. This type of machine offers low productivity and inconsistent product quality due to its dependence on the operator's skill level. In semi-automatic heat press machines, the upper pressing plate is automatically controlled, whereas the lower pressing plate must still be manually moved by the operator when transferring products into the pressing position, resulting in lower efficiency and increased manual operations.Therefore, in order to overcome these limitations and to gain mastery over the design and fabrication technology, it is necessary to conduct research on automatic heat press machine design. The proposed automatic heat press machine utilizes a pneumatic cylinder system with dual pressing stations, helping to reduce processing time. In addition, the machine is scientifically designed to facilitate ease of operation for learners and users, while being capable of pressing various fabric materials and multiple fabric layers.

The automatic flat-plate heat press machine is designed with two pressing tables that can automatically alternate movements to transport products into the pressing position. As a result, a single operator can simultaneously work at two positions, thereby increasing productivity and reducing labor requirements. Furthermore, for teaching, learning, and research purposes, the automatic flat-plate heat press machine serves as an effective educational model, enabling students to gain practical exposure to automated equipment used in the garment industry.

2.2. Operating Principle of the Automatic Heat Press Machine

The automatic heat press machine consists of three main components: the mechanical system, the electrical system, and the actuator mechanism, which utilizes a pneumatic cylinder transmission system. When electrical power is supplied to the system, the cylinder initially moves to its highest position. At this stage, the sliding cylinder is responsible for moving the pressing table containing the product into the pressing position.

Subsequently, the vertical cylinder gradually moves downward to press the product. The pressing duration is preset according to the processing characteristics of the product material. After the predetermined pressing time has elapsed, the pressing cylinder moves upward while the sliding cylinder simultaneously transfers the product table out of the pressing area and stops at the waiting position for product removal. At the same time, the remaining pressing table moves into the pressing position to prepare for the next heat pressing cycle.

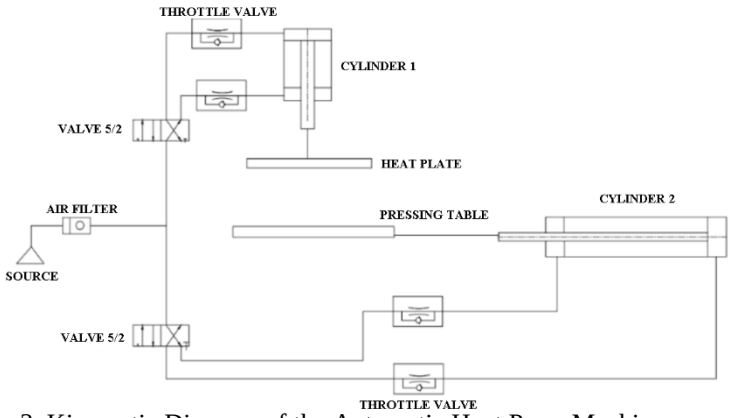

Fig. 3. Kinematic Diagram of the Automatic Heat Press Machine

DESIGN OF THE AUTOMATIC FLAT - PLATE PRESS MACHINE MODEL

3.1. Development of the Design Methodology

The mechanical components constituting the heat press machine, including the machine frame, pressing table, guide system, sliding bearings, and related assemblies, were designed to satisfy technical standards through detailed manufacturing and assembly drawings.

The actuator mechanism was designed by calculating the required parameters for selecting suitable pneumatic cylinders. These calculations included pressing force, pushing force, pulling force, and cylinder stroke. Pneumatic cylinders were then selected according to standard specifications consistent with the calculated requirements. In addition, the kinematic diagram of the system was established, and both 2D and 3D designs were developed using specialized software such as AutoCAD and SolidWorks.

The control system, including the temperature control and heating unit, was designed based on the characteristics of the input materials. Different fabric types possess distinct properties, resulting in varying heating temperatures and pressing durations. Accordingly, a temperature control system was developed to meet these operational requirements. Similarly, the time-control programming for each pressing cycle was implemented. The entire control process was programmed on a PLC platform using GX Works2, which is specifically designed for Mitsubishi Electric PLC systems.

The pneumatic control system was designed according to the characteristics of the input materials in order to determine the appropriate heating duration corresponding to the operating time of the pneumatic cylinders. This system includes sensors, limit switches, and combined valve units. The pressure control of the cylinders was programmed through the PLC system based on sensor feedback, while manual adjustment could also be achieved directly through the air compressor pressure regulator.

3.2. Design of the Heat Press Machine Model

Standard mechanical components such as pneumatic cylinders, throttle valves, check valves, relays, sensors, pumps, and the PLC system are commercially available standard devices; therefore, they must be carefully calculated and selected to ensure compatibility with the system requirements.

The components designed according to calculated dimensions, including the machine frame, pressing table, mounting plates, guide mechanisms, support brackets, and linear sliding bearings, were manufactured through conventional machining processes such as cutting, milling, turning, welding, drilling, and reaming. Accordingly, it was necessary to establish suitable machining procedures, technical requirements, and appropriate cutting parameters for the fabrication process.For the PLC control system, the wiring diagram and component selection were designed based on the operating principle of the machine in order to ensure appropriate integration of all control devices and system elements.After fabrication, all components were assembled and experimentally tested. Control programs were configured for the control units, followed by machine startup and operation according to the designed working procedure. Finally, the operational performance of the equipment as well as the quality of the processed products were evaluated and assessed.

Fig. 4. Front View of the Heat Press Machine

Fig. 5. Side View of the Heat Press Machine

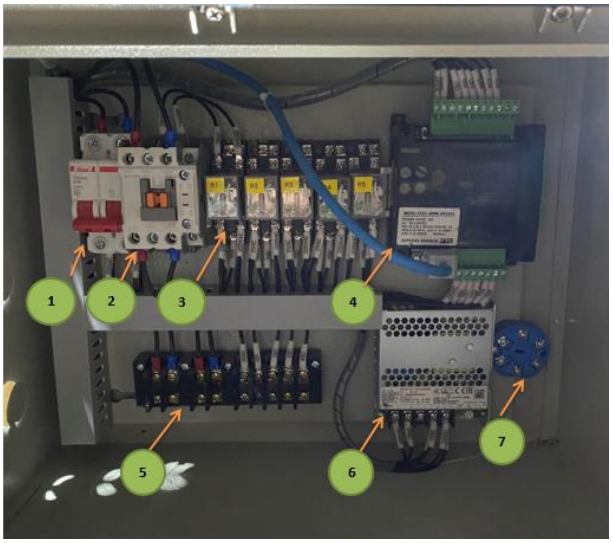

Fig. 6. Electrical Control Cabinet of the Machine

Notes: The number on fig (1: Main power circuit breaker, 2: Contactor for the heating resistor power supply, 3: Intermediate relay for pneumatic cylinder control power supply, 4: PLC controller unit, 5: Terminal block, 6: 220 VAC/24 VDC powerconverter supplying power to the PC and HMI, 7: Temperature converter module).

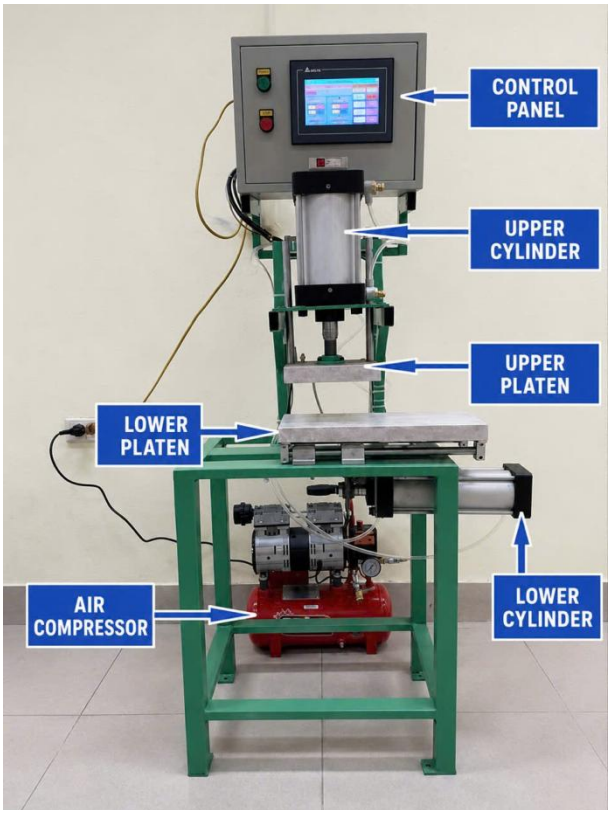

Fig.7. Automatic Heat Press Machine Model

Fig. 8. HMI Interface Display

Remark: The fabrication of the automatic flat-plate heat press machine was successfully carried out through comprehensive research on the mechanical system, actuator mechanism, and control system, together with the development of an appropriate design and manufacturing methodology that satisfied the proposed requirements. Based on the analysis of the product input parameters, suitable operating parameters for the heat press machine were determined, and an automatic flat-plate heat press machine was successfully designed and fabricated.

CONCLUSION

The research successfully developed a design procedure for several mechanical components, along with methodologies for the design and fabrication of an automated mechanical device used in the garment industry. In addition, the study established a method for simulating machine operation through 3D design software. Based on these research outcomes, the paper presented a successful fabrication method for an automatic heat press machine model using a PLC-

based control system.The machine was experimentally tested under various operating parameters, including temperature, pressing time, and pressing force. The experimental results demonstrated stable machine performance and satisfactory product quality. The developed model can be effectively applied in teaching and research activities for lecturers and students in the Faculty of Mechanical and Electrical Engineering, Hanoi Industry and Trade University.

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