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Research Paper

A Study on Design and Manufacture of Automatic Book Binding Machine

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Abstract
This paper presents a study on the design and development of an automatic book binding device, which offers a solution to replace manual binding methods that are still commonly used in small-scale printing facilities. The novel device is developed to automate the binding process by using an Arduino Uno microcontroller. The design of the device components and the operation simulation were done on PTC Creo Elements/Direct Modeling software. Based on them, the real automatic binding device were constructed by using aluminum profiles, off-the-shelf parts, and custom components fabricated with 3D printing technology. The obtained equipment exhibited the good binding performance for A4 and A5 paper sizes and can staple books up to 100 pages thick. On this device, the documents after being neatly folded will be put on the conveyor belt, which will bring the them to the stapling stage, then stickthe adhesive tape on the spine, and cut and fold the edges of the adhesive tape on the spine automatically. It is the biggest difference of this device compared to the existing ones, which will contribute to increase the productivity, ensure the consistency in mass production, and enhance the aesthetic quality of the final bound books. Also, the system is designed to be flexible, easy to maintain, and highly applicable in real-world settings.

Keywords: *Automatic book binding machine; automatic stapling; publishing industry.*

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I. Introduction

In recent years, the demand for automatic devices in the publishing industry has grown significantly due to the need for the growing efficiency, cost reduction, and adaptability to modern publishing models [1]. At the same time, the tighter deadlines and greater pressure to produce high volumes of printed material quickly promote the publishers to find out the automation solutions in order toenhance speed and accuracy across various stages of production [2]. The application of such the devices as automated printing presses, binding machines, and finishing equipment streamline operations by reducing manual labor and minimizing errors.

Additionally, the issues on labor shortages and rising operational costs have made automation even more attractive, which will allowthe publishers to maintain productivity with fewer human resources [2,3]. In the stages, especially in the small workshops, the binding process is often done manually, leading to uneven stapling positions, so the paper can be bent, making it difficult to open documents and reducing the durability of the book. Moreover, uneven gluing of the spine of the book and the location of the tape cutting are also common problems in the binding process, causing the loss of aesthetics for the books [4]. Hence, the utilization of the automatic binding devices that integrates many features will be the optimal solution to help the book be bound evenly, aesthetically, increase the durability of the book as well as minimize labor resources.

An automatic binding device is a machine used in the publishing and printing industry to efficiently bind printed materials such as books, magazines, brochures, and manuals. These machines automate the binding process, which may include aligning pages, applying adhesive, stitching, or inserting binding materials like coils or covers. There are several types of automatic binding devices, each suited to different formats and production volumes. Perfect binding machines, for example, are commonly used for paperback books and magazines, applying hot glue to the spine and attaching a cover automatically. Saddle stitching machines are ideal for booklets and catalogs, folding pages and stapling them along the spine. Coil or spiral binding machines insert and crimp plastic or metal coils through punched holes, making them suitable for notebooks and manuals. Case binding machines are used for hardcover books, automatically attaching the book block to a rigid cover [5]. However, these types of machines are often used in bath and mass production facilities with high investment costs and are only effective in mass production. Therefore, the author is motivated to design and fabricate an automatic book binding device for small printing workshops.

II. Methodology

2.1. Binding process

In this automatic bindind device, the process is carried out in the following steps:(1) stapling, (2) stick the adhesive tape on the spine, (3) cut the adhesive tape,and (4) fold the edges of the adhesive tape on the spine.

2.2. Device specifications

The 3D design model of the automatic bindind device is shown in Figure 1. The proposed binding device consists of the following main parts:

- Conveyor belt: the documents are moved along and stopped at the correct position according to the system.
- Stapling unit: the documents are stapled in two positions
- Cutting and pasting unit: the adhesive tape is sticked on the spine and cut.
- Folding unit: the edges of the adhesive tape are folded on the spine

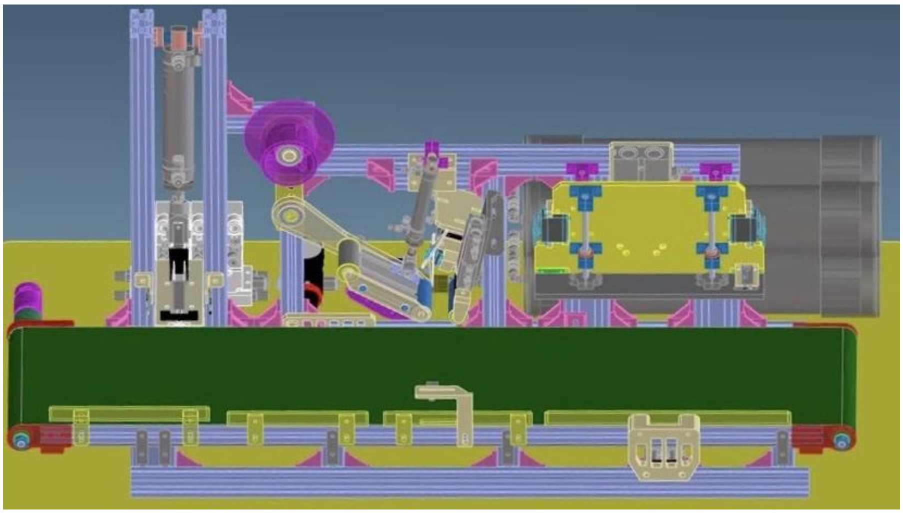

Figure 1. 3D design model of theautomatic bindind device

2.3. Design of the actuator components

-Conveyor parts

The PVC belt conveyor with width 210mm is chosen, and its length is calculated with the following formula [6].

$$L = \frac{\mathrm{D} + \mathrm{d}}{2} \times \pi + 2C = \frac{4 + 4}{2} \times \pi + 2 \times 1143 = 2299\ (mm)$$

Where:
L = the belt length (mm)
C = the center distance of two pulleys (mm)
D = the large pulley diameter (mm)
d = the small pulley diameter (mm)

- Stapling unit

Figure 2 shows the 3D model of the stapling unit and real parts. The pneumatic cylinder having the designation of MAL40X100-CA is used [7], and its parameters are given below:
Cylinder diameter: D = 0.04 m
Pneumatic pressure: p = 0.5 × 106 N/m^2
The stapling force is calculated by the following formula:

$$F = p \times S = p\ \times \pi \times (\tfrac{D}{2})^2\ =\ 0.5 \times \pi \times (\tfrac{0.04}{2})^2 =\ 628.3\ (\mathrm{N})$$

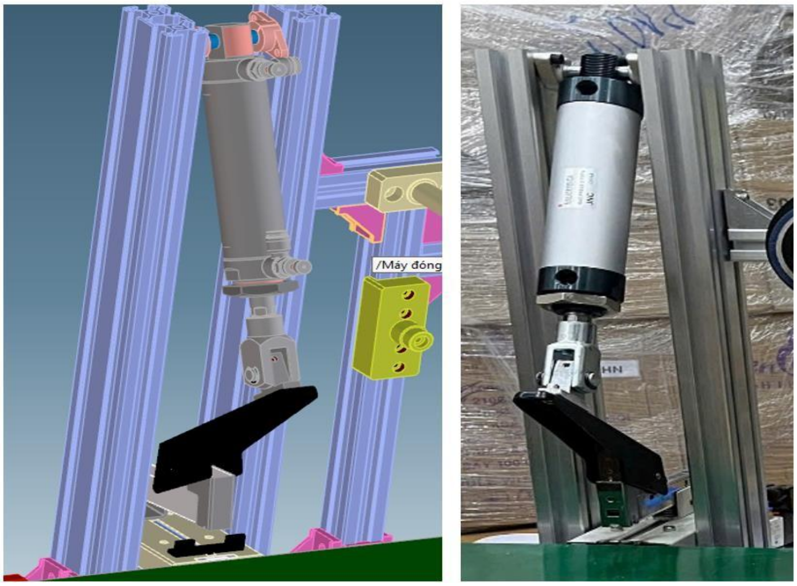

Figure 2. 3D model of the stapling unit and real parts

- Components for sticking and cutting the adhesive tape

Figure 3 presents the 3D model and real components for sticking and cutting the adhesive tape. The mechanism for sticking the adhesive tape includes only one roller to attach the tape roll, one guide roller, one guide unit assembled with the tape holder, and a roller to press the tape onto the document. The tape cutting mechanism is composed of a scissors mounted with MG996R Servo motor and double air cylinder.

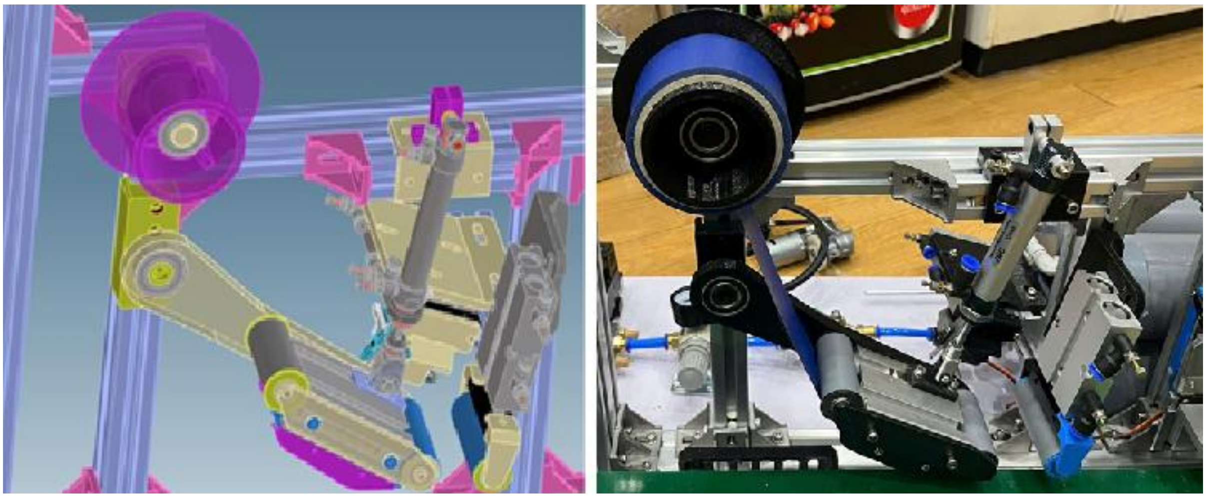

Figure 3. 3D model and real components for sticking and cutting the adhesive tape

- Components for folding the adhesive tape edges on the spine

Figure 4 illustrates the 3D model and real components for folding the adhesive tape edges on the spine. The folding assembly is divided into many transmission levels. The first level has the function of lifting and lowering the entire folding assembly. The entire assembly is lifted and lowered by a TN25x60 air cylinder with a stroke of 60mm and guided by two SCS8LUU round sliders on both sides. The second level is assembled with the purpose of holding the document for the third level to fold the spine tape. The operation of this level is based on the sliding mechanism of the shaft when using self-lubricating copper bushings combined with springs and shaft locking rings. The third level is intended to fold the tape to complete the product.

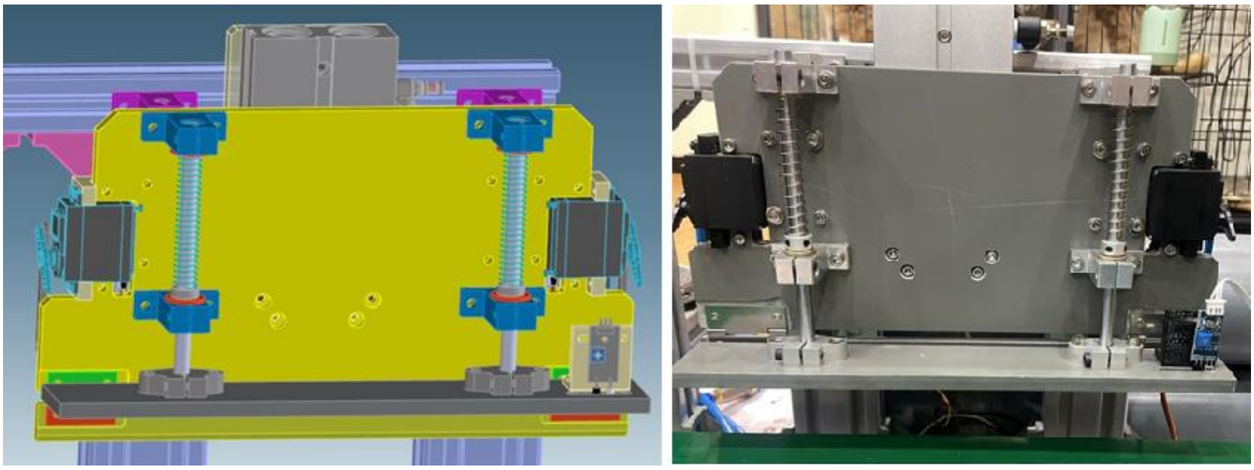

Figure 4. 3D model and real components for folding the adhesive tape edges on the spine

2.4. Control circuit design

Figure 5 shows the schematic diagram of the control circuit, which is composed of a low voltage circuit and a high voltage circuit. The LM2596 step-down circuit is used for four LM393 sensors, two ESP32 boards, three MG996R servo motors, 74HC595N IC expansion board module. The XL6009 step-up circuit contains eight connection ports from JP6 to JP13, in which JP3 port receives honeycomb power, and JP4 port is spare.

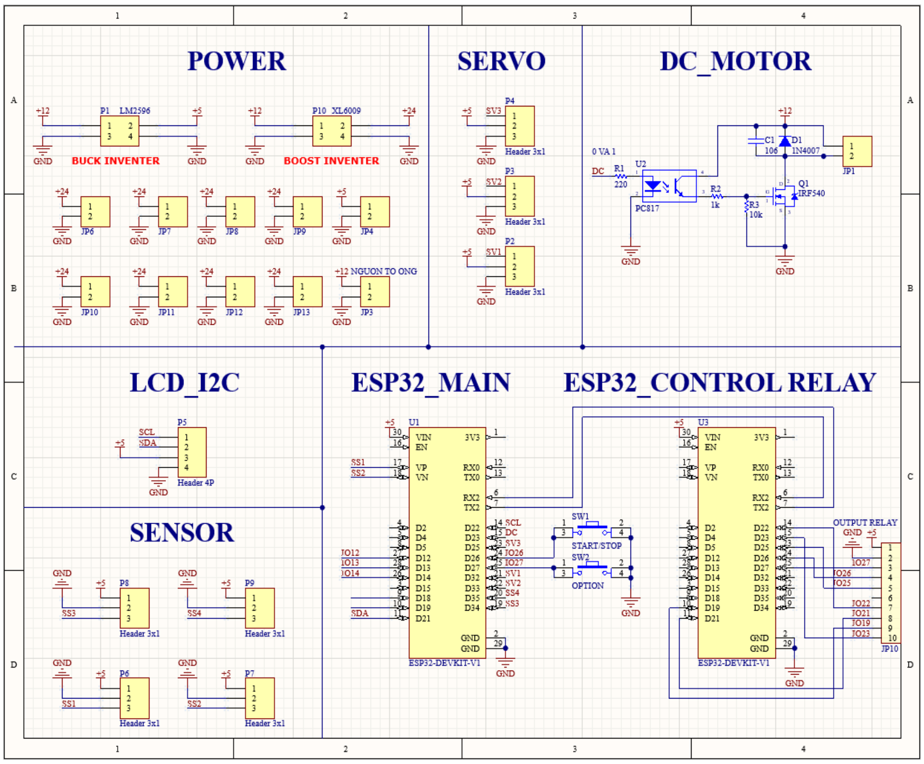

Figure 5. Schematic diagram of the control circuit

2.5. Flow chart of system control algorithm

Figure 6 is the flow chart of system control algorithm, which can be described as below

- Start: The system starts when the "Start" button is pressed.
- The sensors 1 and 2 detect a book on the conveyor. If there is a book, the conveyor moves; otherwise the system waits.
- Stapling: When the sensor 1 does not detect the next document, the conveyor stops and the stapling mechanism is activated to fix the document.

- The sensor 3 detects whether the document is stapled or not. If it is "TRUE", the conveyor stops to push the material into the fixing frame and then lowers the two tape gluing mechanisms.If it is "FALSE", the system continues to wait or perform the next steps depending on the status.
- Sticking the adhesive tape: Servo is activated to pull the tape and perform the cutting.
- Sensor 4 detects whether the document is stuck with the adhesive tape or not. If it is "TRUE", the conveyor continues to run.Finally, the tape folding mechanism is lowered and two servos are used to fold and fix the tape.
- Completion: After completing the above steps, the binding process for the document is done and the system is ready for the next cycle.

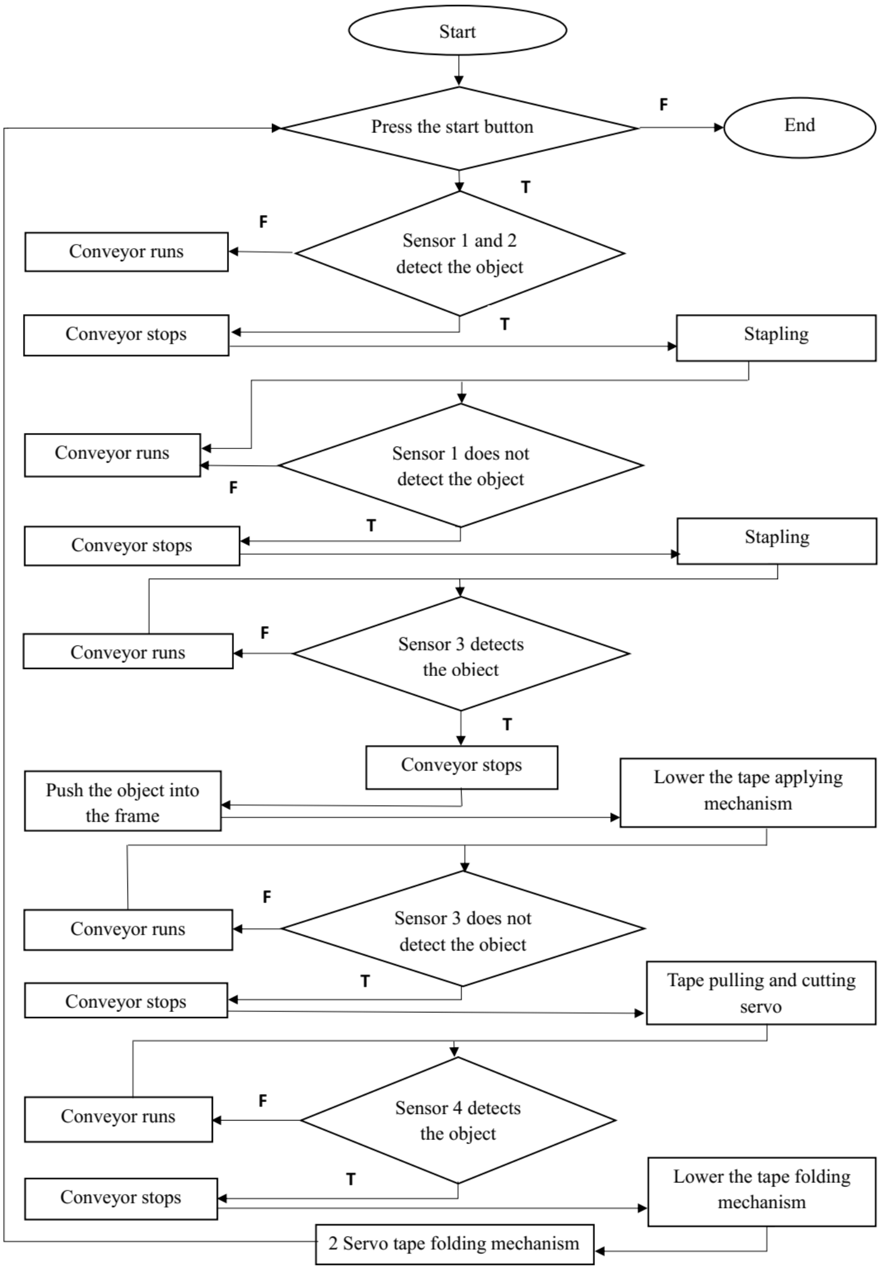

Figure 6. Flow chart of system control algorithm

III. Results and Discussion

Based on the investigation of available equipment on the market and the parts that need to be manufactured, the overall design plan for the automatic binding device was built. The arrangement plan of the basic components includes the system frame unit, conveyor unit, stapling unit, gluing unit, air unit, spine folding unit, control panel system. Thereby, the 3D design model of the automatic binding machine was built with an overall size of 1200x600x550mm (Figure 7).

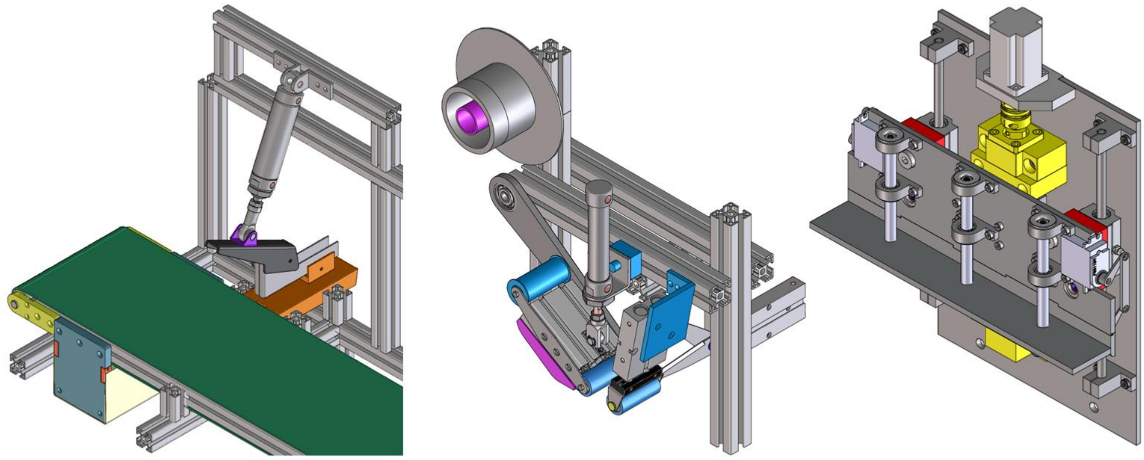

Figure7. Main structural assemblies of automatic book binding device.

Based on the design of the main assemblies, the parts were designed and planed to assemble and fix the available components together. The design of the system frame was calculated and planed properly. The assembly parts will be processed by using the FDM 3D printing method with ABS plastic material (Figure 8).The system frame is made of 3030, 3060 aluminum profiles and square brackets to assemble the sections [8]. The design of the frame shape is shown in Figure 9.

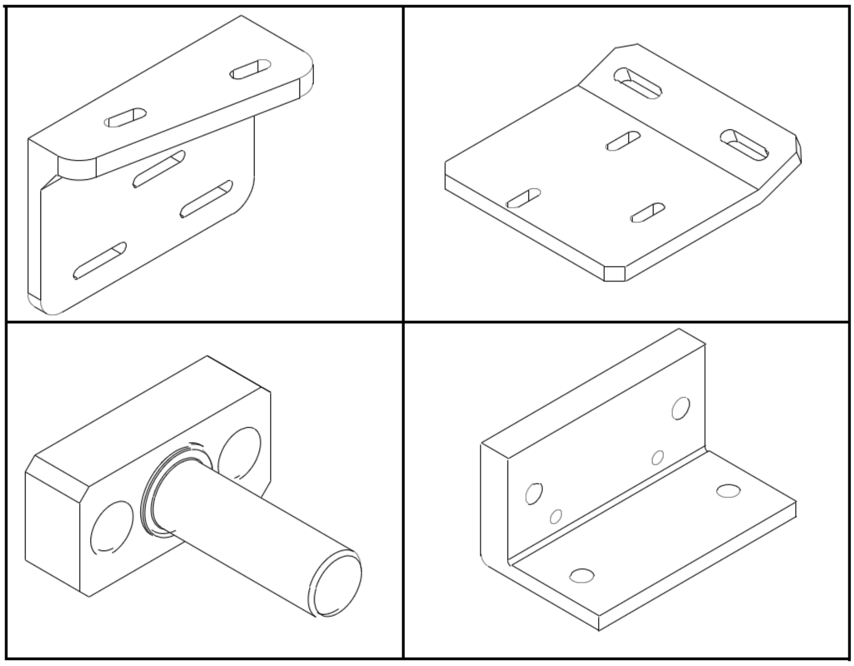

Figure8. Parts made by 3D printing technology

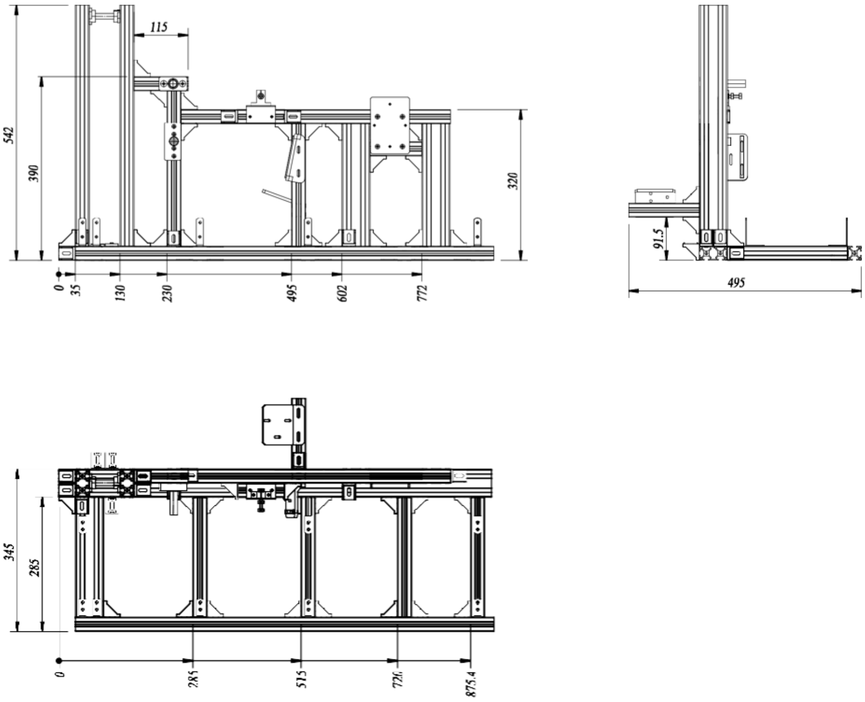

Figure9. Design of the frame shape

The designof the control system was built for the automatic binding machine. The system uses Arduino Uno as the central controller, integrating the sensors, limit switches, pneumatic cylinders, gear motors, and servo motors. The control interface has two modes: automatic and manual, which increases the flexibility of operation.

For the electrical part of the system, the system's power source includes 01 DC 12V 5A honeycomb source to supplythe power to the entire system. Then it is reduced to 5V by a DC-DC step-down circuit to supply power to devices using 5V voltage such as ESP32, infrared sensors, and so on, and it is increased to 24V by a DC-DC step-up circuit to supply power to devices using 24V voltage.

The HMI interface includes an LCD screen that displays the system name, operating status, counts the number of bound books, and reports the number of staples left in the machine. Engineers can reset the product number and select the number of staples added to the machine. Figure 10 shows the electronic components used in the automatic binding machine and their functions.

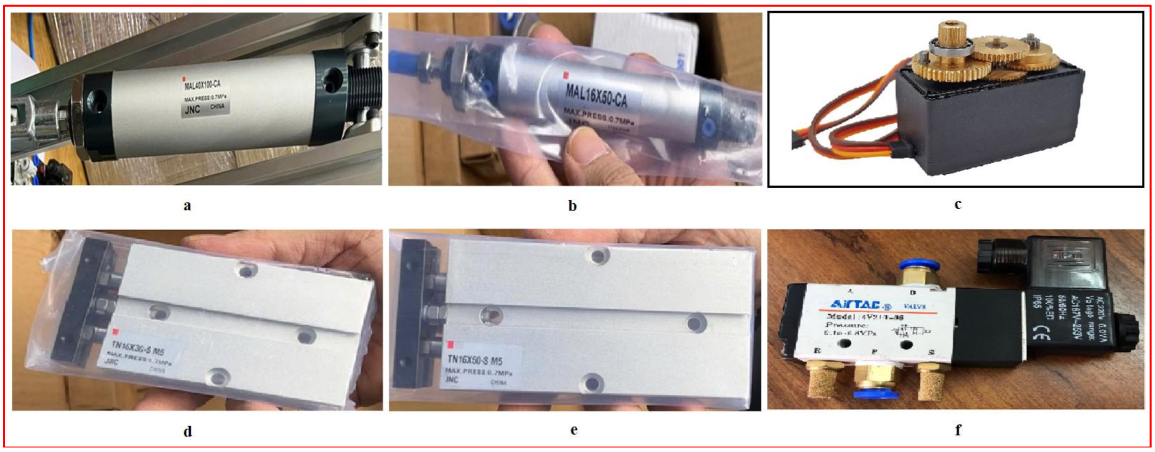

Figure 10. Electronic components used in the automatic binding machine: (a) Round cylinder JNC MAL40x100-CA to push the stapler, (b) Round cylinder JNC MAL 16X50-CA to press the roller to stick the tape, (c) Servo motor MG996R to fold the tape spine, (d) Double shaft cylinder JNC TN 16X30-S M5 to press the tape tightly after sticking, (e) Double shaft cylinder JNC TN 16X50-S M5 to pull out the scissors to cut and retract the scissors when the cutting is finished, (f) Electronic valve Airtac 4V210-08 (5/2 valve) to open and close the pneumatic line.

IV. Conclusion

In this article, an automatic book binding device was designed and fabricated to replace manual binding activity. PTC Creo Elements/Direct Modeling software was used to design, calculate, and construct the 3D models, from which the manufacture processes for the device components was done. The obtained equipment was tested and can staple books up to 100 pages thick with A4 and A5 paper sizes. The stages of stapling, stickingthe adhesive tape on the spine, cutting and folding the edges of the adhesive tape on the spine can be done automatically, which is the novelty of the proposed device. The time for a book binding cycle is about one minute. In the future work, the device can be expanded with additional features such as automatic paper size recognition and connection for remote monitoring.

Acknowledgments

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Reference

[1]. Marc Vermeulen,Samuel M. Webb, Susan Russick, Alicia C. McGeachy, Karissa Muratore, Marc S. Walton. Identification, transformations and mobility of hazardous arsenic-based pigments on 19th century bookbindings in accessible library collections, Journal of Hazardous Materials, 454, 15(2023), 131453, https://doi.org/10.1016/j.jhazmat.2023.131453.

[2]. J.O.W. Poynton, S. Wilde, J. Bourne, E. Jordan, N. Templeton, B. Matheson, T. Capelli, A. Seller, Development of SLA 3D printed volumes for leak testing of LHC Hi-Lumicryomodules at STFC, Vacuum, 234 (2025), 114090, https://doi.org/10.1016/j.vacuum.2025.114090.

[3]. Paro, E., Benvestito, C., Pugliese, S. et al. Study and characterization of paper bookbindings from 16 to 18th stored in the Marciana National Library (Venice). HeritSci 12, 221 (2024). https://doi.org/10.1186/s40494-024-01339-6

[4]. Delbey, T., Holck, J.P., Jørgensen, B. et al. Poisonous books: analyses of four sixteenth and seventeenth century book bindings covered with arsenic rich green paint. HeritSci 7, 91 (2019). https://doi.org/10.1186/s40494-019-0334-2

[5]. Albertin F, Balliana E, Pizzol G, Colavizza G, Zendri E, Raines D. Printing materials and technologies in the 15th–17th century book production: an undervalued research field. Microchem J. 138 (2018),147–53. https://doi.org/10.1016/j.microc.2017.12.010.

[6]. PrzemysławRumin, JanuszKotowicz, Daniel Hogg, Anna Zastawna-Rumin, Utilization of measurements, machine learning, and analytical calculation for preventing belt flip over on conveyor belts, Measurement, 218 (2023), 113157, https://doi.org/10.1016/j.measurement.2023.113157.

[7]. Hongliang Hua, Jing Zhang, Che Zhao, Zhilin Wu, Jie Song, Zhenqiang Liao, Prediction-based rapid force control of a single-acting pneumatic cylinder under hysteresis nonlinearity, ISA Transactions, 158 (2025), 686-696, https://doi.org/10.1016/j.isatra.2025.01.026.

[8]. PRN Childs, Mechanical Design Theory and Applications, 3rd ed (2021), Elsevier.