

**THE UNIVERSITY OF DANANG
UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING**

**CAPSTONE PROJECT
MAJOR: MECHATRONIC ENGINEERING**

THESIS TOPIC:

**A DESIGN OF MACHINE FOR MAKING
A COVER OF THE VOICE USING IN
HEADPHONE**

Supervisor: Dr. PHAM ANH DUC
Co-supervisor: Mr.DINH DUY HUNG
Reviewer: Dr.VO NHU THANH
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Class: 20CDT1

Da Nang, 06/2025

SUMMARY

Project topic: A Design Of Machine For Making A Cover Of The Voice Using In Headphone

Student: Dinh The Huynh Student ID: 101200228
Le Van Cuong Student ID: 101200217

Class: 20CDT1

1. Actual needs of the topic:

In the field of audio equipment manufacturing, especially speakers and headphones, voice coils are important components that determine sound quality and performance. An indispensable step in the voice coil manufacturing process is tape gluing to fix, insulate and protect the coil structure. However, many factories still perform this step manually, leading to many limitations such as incorrect gluing position, difficulty in quality control, increased labor costs and reduced productivity. In that context, the need to automate the tape gluing process becomes extremely urgent, contributing to improving production efficiency and ensuring accuracy and consistency in each product.

2. Scope of research of the topic

The topic focuses on the design and manufacture of an automatic tape-applying machine specifically for voice coils. The research content includes:

- Design the mechanical structure of the machine, including tape gripper robot, pneumatic cylinder system, jig positioning – clamping – rotating mechanism and tape rolling system.
- Build control algorithms and programming using Keyence PLC, combining sensors and peripherals.
- Integrate the system into the production line and conduct real-world testing to evaluate operational performance.

The topic does not delve into advanced HMI software design or machine vision integration, but focuses on basic, effective and feasible solutions in real production conditions.

3. Content of the topic has been implemented

- Number of pages: 92
- Number of drawings: 7 A0 drawings
- Model: 1

4. Results achieved

The result of the project is a stable tape gluing machine system, capable of replacing manual operations, ensuring the requirements of:

- Accuracy in paste placement
- High repeatability, suitable for mass production
- Save cycle time, increase productivity
- Automatically detect errors and stop the system safely

The process of implementing the topic also helps the implementer improve professional skills in control programming, mechanical design and system thinking, while clearly demonstrating the practical application of the learned knowledge in the industrial production environment.

GRADUATION PROJECT ASSIGNMENT

TT	Student name	Student card number	Class	Branch
1	Dinh The Huynh	101200228	20CDT1	Mechatronic Engineering
2	Le Van Cuong	101200217	20CDT1	Mechatronic Engineering

1. *Project title: A Design Of Machine For Making A Cover Of The Voice Using In Headphone*

2. *Topics include: Signed intellectual property agreement for implementation results*

3. *Initial figures and data:*

- Required data on components, manufacturing range , system capacity as required by Foster Vietnam company.
- System specifications provided by Foster Company – Vietnam .
- Materials: Aluminum profile, stainless steel, steel, plastic

4. *Contents of the explanation and calculation sections:*

a. General part:

TT	Student name	Content
1	Dinh The Huynh	<ul style="list-style-type: none"> • Chapter 1: Introduction • Chapter 5: Conclusion
2	Le Van Cuong	

b. Private part:

TT	Student name	Content
1	Le Van Cuong	<ul style="list-style-type: none"> • Chapter 2: Structral Design
2	Dinh The Huynh	<ul style="list-style-type: none"> • Chapter 3: Control Design • Chapter 4: Results

5. *Drawings, graphs (specify types and sizes of drawings):*

a. General

TT	Student name	Content
1	Dinh The Huynh	<ul style="list-style-type: none"> • Overall system drawing: 1 A0
	Le Van Cuong	

b. Private part

TT	Student name	Content
1	Le Van Cuong	<ul style="list-style-type: none">• Detailed drawing: 5 A0
2	Dinh The Huynh	<ul style="list-style-type: none">• Algorithm flowchart drawing :1 A0• Electrical diagram drawing: 1 A0• Dynamic diagram drawing: 1 A0

6. *Instructor's name:* Dr. Pham Anh Duc

7. *Project assignment date:*

8. *Project completion date:* June 3, 2025

Da Nang, June 3, 2025

Head of Department

Instructor

FOREWORD AND ACKNOWLEDGEMENTS

In the context of industrialization, modernization and the strong development of the audio technology industry, voice coils - also known as voice coils - have become one of the core components that determine the quality and performance of devices such as speakers, headphones, microphones, and many other audio transmission systems. With the increasing demand for products with superior precision and quality, building a modern, synchronous voice coil production line and optimizing the production process is a key factor for businesses to improve their competitiveness, master technology and develop sustainably.

When participating in the project in our company, we learned about the overview of the voice coil production line, from the technical process, applied technology, to the quality standards that need to be met. Through that, we hope to bring a comprehensive view and basis for orientation for investing, operating and developing the voice coil production system effectively and professionally.

In this capstone project, we directly participated in the research and development of the **A design of machine for making a cover of the voice using in headphone**, which is a machine in the voice coil production line at the company. During the project research, the group received guidance and assistance from the company's engineers, and enthusiastic guidance from Mr. Pham Anh Duc, helping us to complete this project and achieve good results.

First of all, we would like to send our sincere greetings, best wishes and deep thanks to the teachers in the Faculty of Mechanical Engineering - Danang University of Technology. With the teachers' care, teaching and dedicated guidance, the group of authors has been able to complete this topic . In addition, we would like to thank the enthusiastic and experienced engineers of FOSTER Company, the help and knowledge sharing from our classmates and the great support in terms of funding and materials from FOSTER Da Nang. Finally, the group would like to send our most sincere thanks to the teacher - Dr. Pham Anh Duc for his attention, help and guidance to help the group of authors complete this topic well in the past time.

With the limited knowledge and experience of the authors, this topic cannot avoid shortcomings. The authors are looking forward to receiving guidance and comments from teachers so that the authors can supplement and improve their knowledge, better serving future practical work.

The author team sincerely thanks!

Da Nang , May 13 , 2025

Project Implementer

Dinh The Huynh Le Van Cuong

ASSURE

To the Faculty of Mechanical Engineering – The University of Da Nang
University of Science and Technology

We hereby certify that the project complies with the following regulations on academic integrity:

- Do not use any form of deception in presenting your academic activities or results from your academic studies.
- Do not fabricate or provide false information from the cited source.
- Do not falsify data during surveys, experiments, practices, internships or other academic activities.
- Do not plagiarize, use other people's words, quotes, expressions as if they were your own, present, copy, translate passages, or state other people's ideas without citation.
- Do not plagiarize yourself, reuse your own research information without citation, or fragment your research results to publish in multiple publications.

Student practice

Dinh The Huynh Le Van Cuong

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CHAPTER 1: Introduction

1.1 FOSTER company

1.1.1 History

Foster Electronics Vietnam Co., Ltd. is a member of Foster Group Japan, specializing in the production of headphones (ear-bud; earphone).



Figure 1.1: Image of FOSTER company [Source: Internet]



Figure 1.2: Products made by FOSTER [Source: Internet]

As a 100% foreign-invested enterprise, the investor is Foster Tokyo. The investor will have the right to appoint or dismiss members of the board of directors.

+ Company name: Foster Electronics Company Limited (Vietnam)

- + English name: Foster Electric (Viet nam) Co.,Ltd
- + Head office: No. 20, Road No. 5, Vietnam-Singapore Industrial Park II, Hoa Phu Ward, Thu Dau Mot City, Binh Duong Province, Vietnam.
- + Tel: 84-274-3635050
- + Fax: 84-274-3635051
- + Establishment license number: 164/GP-KCN-VS
- + Tax code: 3700689599
- + Bank account:
 - Mizuho Bank
 - Vietcombank, Binh Duong branch
 - Dong A Bank
 - Bank of Tokyo
- + In January 2006, the Company was established and registered in Vietnam under the name Foster Electronics Company Limited (Vietnam).
- + June 2006 started producing headphones at Estec facility to train workers.
- + September 2006 started production at Foster 1 factory (FV 1).
- + December 2006 received QMS ISO 9001:2000 certificate.
- + September 2007 started production at Foster 2 (FV2) factory.
- + June 2008, established Foster factory in Da Nang, abbreviated as FVD 1.
- + In September 2008, Foster 2 plant expanded with a plastic molding workshop.
- + March 2010, established Foster factory in Bac Ninh.
- + In December 2011, Foster Mecong factory was established in Da Nang, abbreviated as FVDM.
- + August 2012, established Foster factory in Quang Ngai, abbreviated as FVDQ
- + In July 2013, Foster 1 factory was closed and workers were moved to the headquarters at Foster 2.
- + In 2011, Foster Vietnam Electronics Co., Ltd. entered the top 500 largest private enterprises in Vietnam, the company was ranked 262nd in the industry ranking "Manufacture of electronic products, household appliances"

Capital scale:

The charter capital of the enterprise is 29,000,000 USD

Total investment: 46,000,000 USD

Of which, the capital contributed to implement the projects is 26,000,000 USD.

Invested in the following projects:

- The investment capital for the factory project in the Vietnam-Singapore Industrial Park is 40,500,000 USD. Of which, the contributed capital to implement the project is 23,000,000 USD, and the capital contribution was completed in April 2008.

- The investment capital for the project to build housing for workers is 5,500,000 USD. Of which, the contributed capital to implement the project is 300,000 USD.

The business operation period is extended from the date of license issuance to February 2046. Any change to this period must be approved by the board of directors and reported to the investment licensing authority for consideration and approval.

The assets of the enterprise will be insured by an insurance company licensed to operate in Vietnam and will not be nationalized, confiscated or transferred to other owners by administrative measures.

Enterprises report their financial statements annually and are audited by an independent auditing company in accordance with Vietnamese law on auditing.

Facilities:

With 3 main workshops, including a total of 63 production lines with a capacity of 42 million products/year. The company specializes in importing raw materials, supplies and equipment for production, exporting headphone equipment and related accessories such as speakers, speaker systems, active speakers, sound transmission systems,...

Number of employees: 13,347 people

Initial capacity: 12,000 products/month

In addition, the company also hired 6 enterprises to sign long-term product processing contracts: VIETROICS Binh Hoa Joint Stock; HUNG MAO Special Electric Wires Co.; ASTEE HORIE Viet Nam Co.; CEI International Investment; AN THINH Technology Co.; TOYOITEC Viet Nam Co.

The company's main customers are Foxconn, one of the world's largest manufacturers of electronic components and computers, as well as Pegatron, which also specializes in manufacturing electronic components, phones, and especially Apple's iPhone...

Main design:

- Conveyor line/ Manual assembly cell line.
- Automatic sound testers (QTA 592 and others).
- Sound level meter and soundproof test room.
- Environmental testing machine (noise, light).
- Standard control room.
- Coil assembly machine.
- Diaphragm frame making machine.
- Magnetic circuit assembly conveyor.
- Rubber mold making machine for wire plug.
- Plastic mold making machine.
- Wire tester.

- Rear case dot matrix printer.

1.1.2 General Company Information

Full name: Foster Electronics Co., Ltd. (Da Nang)

International name: FOSTER ELECTRIC (DA NANG) CO.,LTD

Tax code: 0400643083

Legal representative: Nguyen Quan Hoang

Head office address: Road No. 1, Hoa Cam Industrial Park, Hoa Tho Tay Ward, Cam Le District, Da Nang City, Vietnam

1.1.3 Business fields

Foster Electronics Danang Co., Ltd. is a member of Foster Group Japan , specializing in the production of electronic products, especially audio equipment. The company's main business areas include:

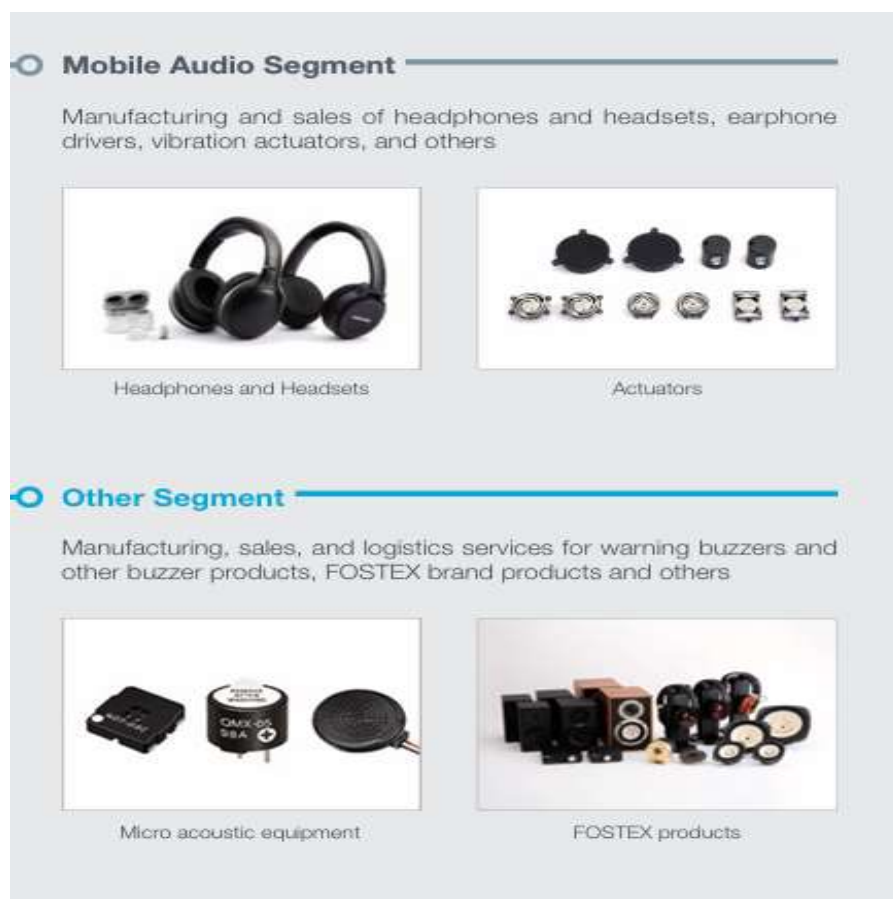


Figure 1.3 Company products [Source: Internet]

1. Production of headphones and audio equipment:

Foster is a supplier of headphones and audio components to major brands around the world.

Products manufactured in Da Nang include headphones, speakers, and high-quality audio components.

2. Electronic components:

The company manufactures precision electronic components for the audio and other equipment industries.

Electronic equipment processing and assembly:

Foster Danang provides processing and assembly services for audio equipment and electronic components according to international standards.

3. Export:

Products from the factory in Da Nang are mainly exported to major markets such as Japan, the US, and Europe.

Foster Group is renowned for its product quality and cutting-edge technology, and its Da Nang factory plays an important role in the group's global supply chain.

1.1.4 Organizational structure of FOSTER company

Company organizational chart and functions and duties of departments

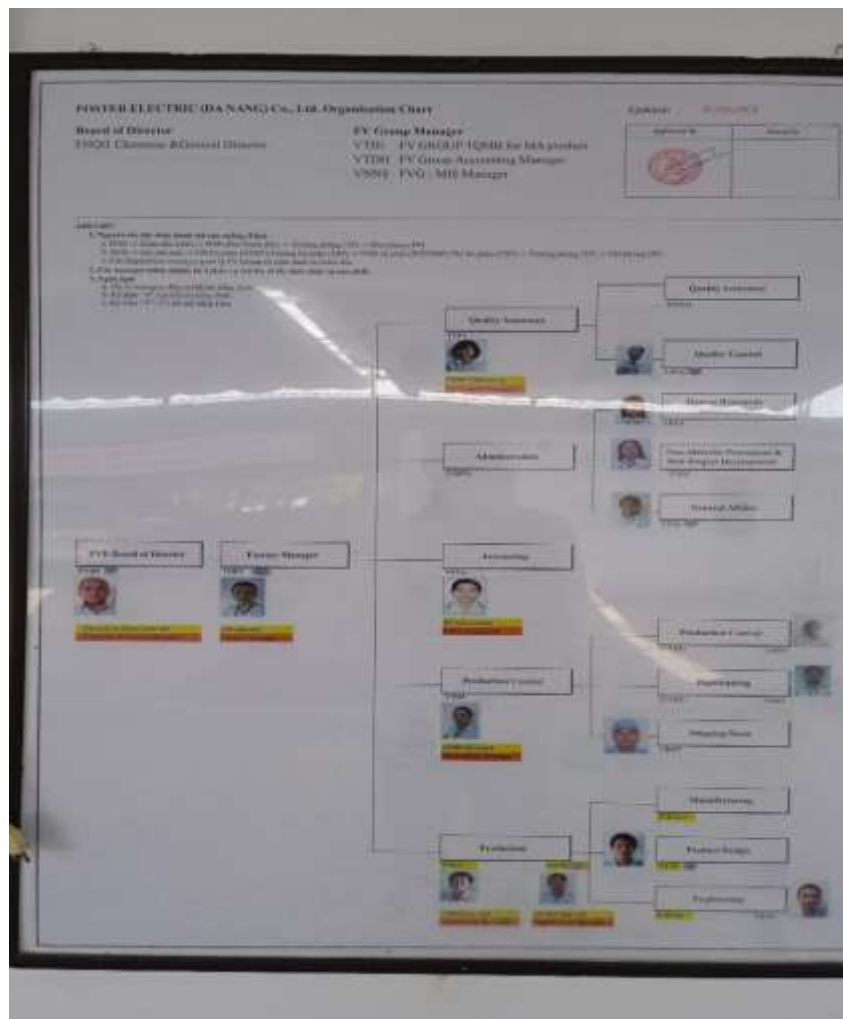


Figure 1.4 Company organizational chart

❖ **General Director.**

Appointed by the Board of Directors to manage and operate the daily business operations of the enterprise and will be responsible to the Board of Directors for all matters in production, business, administrative management, quality and environmental activities.

As the highest executive of the enterprise, and all members of the enterprise will report to the general director. Specifically, the general director has the following rights and responsibilities:

- Report to the board of directors on the business operations of the enterprise.
- Assign subordinate staff through an organizational chart, clearly defining the scope, responsibilities and authority of each person.
- Approve the disposal of nonconforming products and services.
- Supervise and direct the work of all other members of the business.
- On behalf of the enterprise, negotiate, sign and decide on any contracts, documents, and correspondence related to the daily business and administrative operations of the enterprise under the general or specific authorization of the board of directors.
- Conduct all regular quality system management meetings.
- Represent the company before courts, arbitration bodies, state agencies, other competent authorities of Vietnam and all third parties, as well as other lawsuits under the general or specific authorization of the board of directors.
- Ensure that the decisions of the board of directors are implemented provided that such decisions are not contrary to the provisions of the company's charter and Vietnamese law.

❖ **QA department.**

Quality Control Department

- Orientation and approval of quality policies and objectives.
- Ensure the suitability of the quality plan for the correct implementation of customer, product, and system requirements.
- Proactively identify problems in a preventative manner and ensure corrective action is taken.
- Ensure only correct products are stocked and delivered to customers.
- Plan, implement and follow the overall internal audit cycle.

Reliability testing room.

- Maintain accuracy and quality stability of all measuring and testing equipment

Equipment calibration process

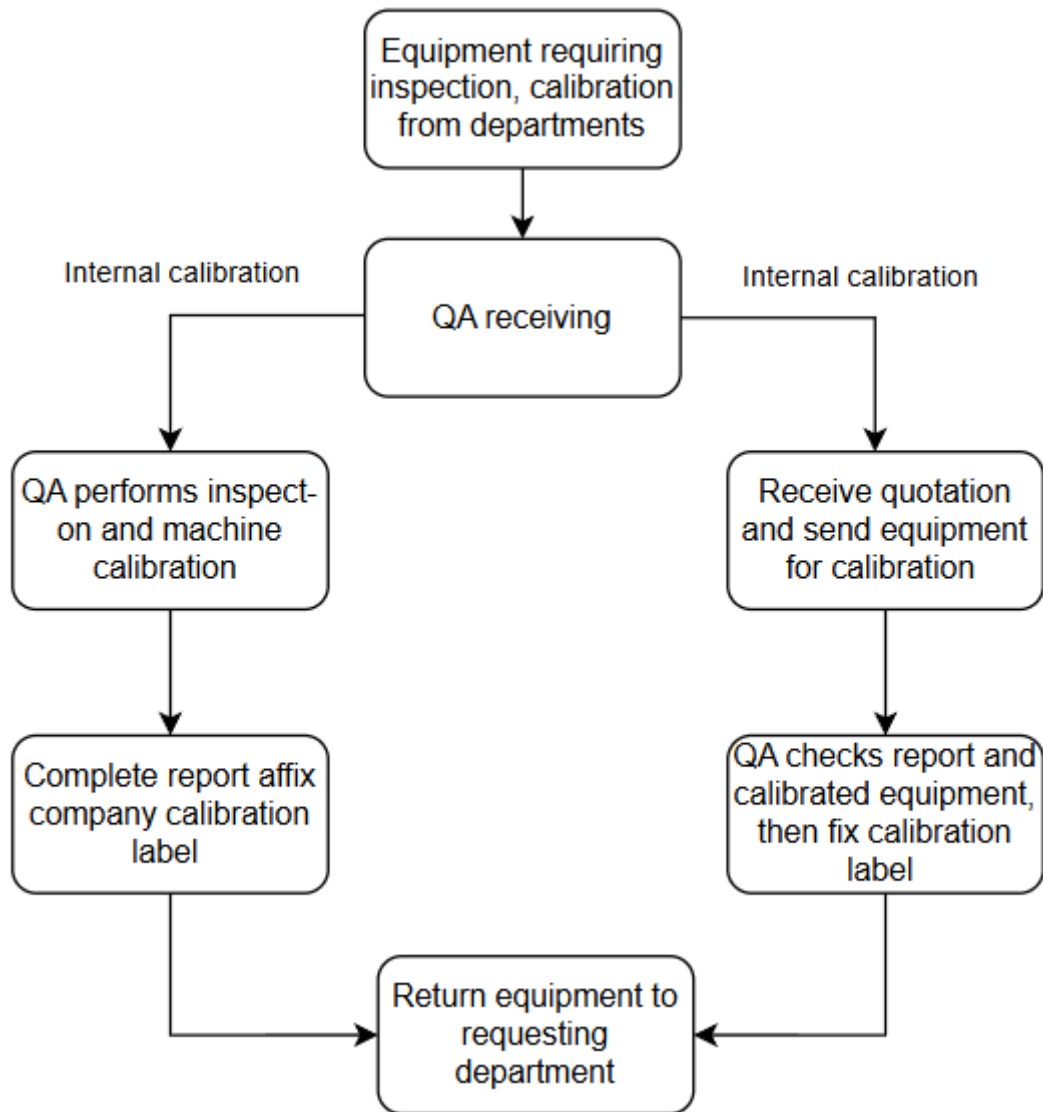


Figure 1.5 Product testing process in foster company

❖ Information management department.

- General Affairs Department

- Resolve issues related to workflow and administrative procedures.
- Support employees in performing daily tasks.
- Keep company records and documents.
- Ensure the security and safety of information.
- Provide uniforms and working tools for employees.
- Manage the use of facilities such as lockers and vehicles.
- Organize and implement 5S activities (Sort, Set in order, Shine, Standardize, Discipline) to ensure a clean and tidy working environment.

- Human Resources Department
 - Taking care of employees' lives: Organizing activities to take care of employees' spiritual and material lives, creating a comfortable and dynamic working environment.
 - Advise the Board of Directors: Make recommendations on human resource planning, recruitment, training, assessment and development of human resources to meet the needs of the company.
 - Develop and implement training programs: Develop training plans to improve professional capacity and skills for employees, contributing to the development of the company's human resources.
 - Salary and bonus management: Develop and implement salary and bonus policies, ensuring fairness and appropriateness to each individual's contribution.
 - Human resource management: Perform tasks related to recruitment, training, employee evaluation, and personnel records management.
 - Manage administrative activities: Manage work related to facilities, vehicles, administrative procedures, ...
 - Company representative in labor relations: Participate in resolving issues related to labor relations, ensuring the rights of employees.
 - Safety and Security Management Department
 - Ensuring the safety of life and health of workers: This is the top and consistent requirement in all production and business activities.
 - Ensuring a safe working environment: Working conditions must meet occupational safety and health (OSH) standards.
 - Identify and control hazardous factors: It is necessary to regularly check, evaluate and eliminate factors that can pose a danger to workers.
 - Regular equipment maintenance: Maintenance of machinery, equipment, factories and warehouses is very important to ensure they operate safely and stably.
 - Propaganda on labor safety: There should be clear signs and regulations on labor safety and regular training and propaganda sessions should be organized to raise awareness among workers.
 - Get union input: Unions play an important role in developing and implementing safety measures.
 - Monitoring and evaluation: There should be a system to monitor and evaluate the effectiveness of occupational safety measures, and regular statistical reports should be provided.
- Purchasing Department (non-materials):
- Function: Ensure adequate provision of equipment, machinery and tools necessary for the production process.

- Mission:
 - Plan and execute purchasing activities.
 - Find a reputable supplier with reasonable prices.
 - Control the quality of goods when entering the warehouse.
 - Inventory management.

MIS Department (Network Management System):

- Function: Manage and operate the company's computer network system.
- Mission:
 - Install, maintain and upgrade network systems.
 - Ensure the network system operates stably and meets work needs.
 - Secure network systems, prevent external attacks.
 - Technical support for users.

Environmental department:

- Function: Managing and protecting the environment during production and business processes.
- Mission:
 - Monitor and update environmental laws and regulations.
 - Assess the impact of production activities on the environment.
 - Develop and implement environmental protection measures.
 - Cooperate with authorities to ensure compliance with the law.

❖ Accounting Department

The accounting department plays an important role in managing the company's finances. Specifically, the department's main tasks include:

Management accounting:

- Collect and process information: Collect, synthesize and analyze data on the company's production and business activities to provide information for leaders to make decisions.
- Business performance analysis: Evaluate the performance of each department, product, and service.
- Financial planning: Develop short-term and long-term financial plans for the company.
- Cost Control: Control expenses to ensure efficient use of capital.

Financial accounting:

Recording economic transactions: Fully and accurately record economic transactions arising during the company's operations.

Prepare financial reports: Prepare periodic financial reports (income statement, cash flow statement, balance sheet) to provide financial information to stakeholders.

Pay taxes: Calculate and pay taxes according to the law.

Capital Management: Managing the company's capital resources, including equity and debt.

Input-Output Control (IOC) Department

- **Function:** This department is responsible for managing and monitoring all activities related to the quantity of goods and materials entering and leaving the company.
- **Main tasks:**
 - **Data entry:** Enter data about orders, products, and materials into the management system.
 - **Warehouse management:** Track inventory, import and export, ensure goods are always complete and accurate.
 - **Costing:** Calculate product cost based on data on materials, labor and manufacturing costs.
 - **Report export:** Provide reports on inventory, production, and revenue to serve management purposes.

❖ Production Control (PC) Department

- **Function:** This department is responsible for planning and controlling the production process to ensure that products are produced on schedule, in quality and quantity.
- **Main tasks:**
 - **Production planning:** Make detailed production plans for each product and each production line.
 - **Production monitoring:** Monitor the production process, ensure products are manufactured according to quality standards.
 - **Progress control:** Control product completion time, ensure on-time delivery.
 - **Balancing resources:** Arrange human resources, machinery, and materials to ensure the production process runs smoothly.

❖ Import and Export Department

The import-export department plays an important role in the company's business operations, ensuring smooth trading of goods with domestic and foreign partners.

Main functions:

- **International trade:**
 - **Planning and implementing import-export contracts:** Building and implementing contracts for the purchase and sale of goods with foreign partners.
 - **Order Tracking:** Closely monitor the order fulfillment process, from order placement to delivery.
 - **Solve problems that arise:** Handle problems that arise during the import and export process such as disputes, damaged goods, and delayed delivery.
- **Production support:**
 - **Provide market information:** Provide information about the market and customer needs so that the production department can adjust production plans.

- Planning support: Participate in the production planning process, ensure sufficient raw materials, machinery and equipment to meet export orders.
- Customs records management:
 - Prepare all customs documents as required.
 - Import and export customs clearance.
 - Resolve customs related issues.
 - ❖ Purchasing Department (materials)

Main functions:

- **Purchasing planning:** Based on the company's production plan, the purchasing department will calculate and plan to purchase the necessary raw materials and consumables to ensure the production process is continuous and uninterrupted.
- **Supply Management:** Conduct research, selection and management of suppliers.
- **Quality and price assurance:** Compare prices and quality of suppliers to choose the best supplier, ensuring goods meet quality requirements and competitive prices.
- **Inventory management:** Track inventory levels, ensure there are always enough raw materials for production without waste.

- ❖ **Technical Improvement Program (PIP)**

Is the department responsible for researching and improving production lines in the factory to improve productivity and work efficiency.

- ❖ **Warehouse:**

- Provide production materials based on the production plan provided by the design department.
- Receive the quantity of finished products from the quality control department into the warehouse, and export finished products as required.

- ❖ **Production department.**

- Plan regular equipment maintenance and repair.
- Monitor the operating status of machinery and equipment.
- Ensure the device always operates stably and efficiently.
- Market research, grasp consumer trends to develop suitable new products.
- Participate in product design process.
- Make detailed production plans to ensure production is on schedule and of good quality.
- Monitor production process, handle arising problems.
- Ensure product quality meets requirements.
- Propose solutions to improve production processes and increase productivity.
- Invest in new technology to improve production efficiency.

1.1.5 Mission and Vision

Mission: To provide high quality audio products that meet the needs of global consumers.

Vision: To maintain the leading position in the field of audio equipment manufacturing and become one of the world's leading reputable suppliers.

1.1.6 Labor safety and product quality

Foster Electronics Danang Co., Ltd., a member of Foster Group Japan, always puts labor safety and product quality first in production activities.

- Reproductive Health Care: With women accounting for more than 95% of the workforce, the company places special emphasis on reproductive health care, promoting gender equality and providing contraceptive education programs for both men and women.
- "3 on-site" model: During the epidemic period, Foster Da Nang has applied the "3 on-site" model (working, eating, resting on-site) to ensure safety for workers and maintain production activities.
- Product quality:
 - International standards: Foster Danang produces products such as speakers and headphones, meeting the strict quality standards of Foster Group Japan and global partners.
 - Technology improvement: The company continuously improves its machinery and equipment system to enhance productivity and product quality, ensuring to meet the increasing demands of the market.
 - Staff training: Foster Danang regularly organizes soft skills training courses and capacity building for employees, to ensure quality in each stage of production .

❖ The Process of Implementing 5S/3D in the Factory

Foster implemented the 5S program in his workplace and it comes from the Japanese words seri, setion, seiso, seiketsu and shitsuke which mean roughly, sorting, cleaning, standardizing, and sustaining.



Figure 1.6 The 5S Rules

With the above steps we have the following specific actions:

- Sort: eliminate unnecessary items.
- Arrange: arrange objects in the right place, according to rules for easy searching
- Cleanliness always keeps the work environment clean.
- Care: always maintain a neat and tidy work environment so that anyone working at the location can find the necessary supplies.
- Readiness: the spirit of self-awareness in implementing 5S of each individual and collective.

1.2 Voice coil production line

1.2.1 Voice coil

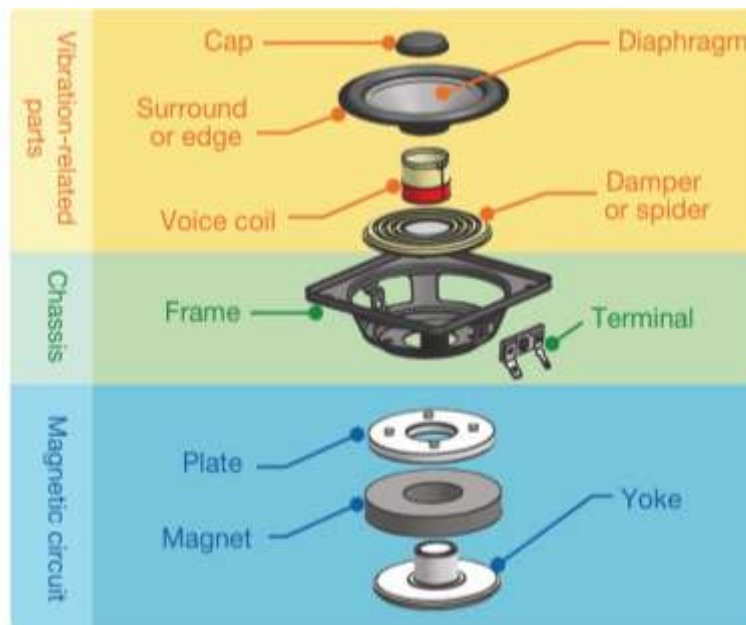


Figure 1.7 Parts of a speaker [Source: Internet]

The voice coil, also known as the voice coil, is one of the most important components in the construction of a loudspeaker. It is responsible for converting

electrical signals into mechanical vibrations – a core process that produces the sound we hear. The voice coil is usually made of highly conductive copper or aluminum wire, wrapped around a cylindrical core and attached to the speaker diaphragm. When the audio current passes through the voice coil, it creates a magnetic field that interacts with the speaker’s static magnet, causing the coil to oscillate rapidly at the signal frequency. It is this vibration that vibrates the speaker diaphragm, producing sound.

The precision in the design and manufacturing of the voice coil directly affects the sensitivity, distortion, and operating power of the speaker. Therefore, in the audio industry, the voice coil is not only a simple electronic component but also a decisive factor in the overall sound quality of the device.

1.2.2 Voice coil production line

Voice Coil Manufacturing Process, to produce a quality voice coil, the process usually includes the following steps:

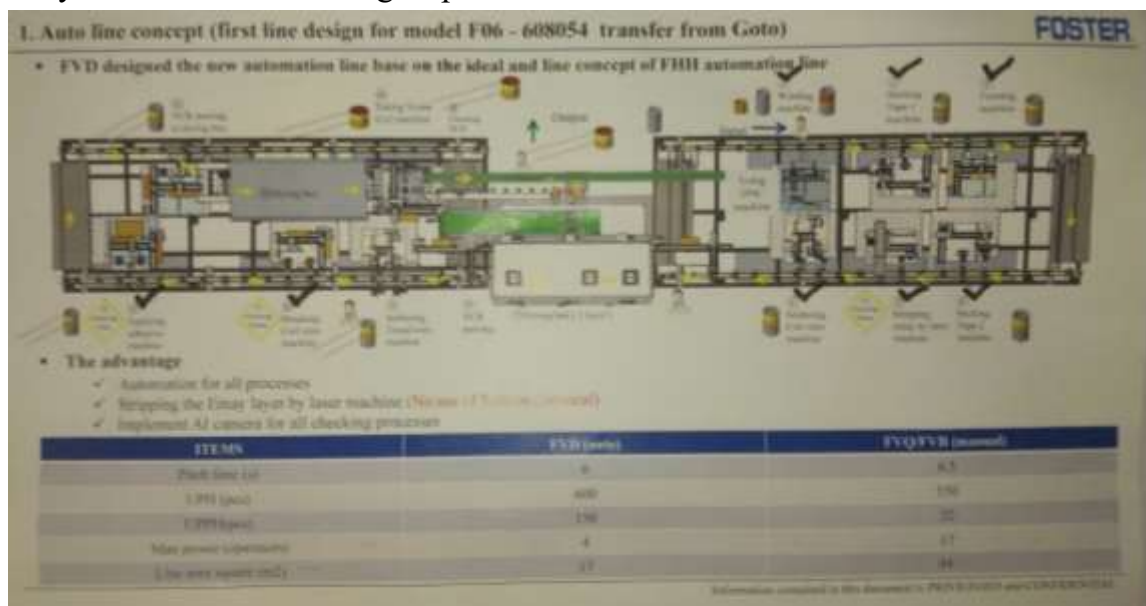


Figure 1.8 Auto line concept [foster]

Layout 1:

- Step 1: Wind the Voice Coil

The worker will carefully put the jig into the mold and be held by the clamping cylinder combined with the coil collar through the automatic winding machine. This process creates layers of copper wire (copper wire coated with insulating glue) wrapped around the coil collar with the required number of turns as programmed.



Figure 1.9 Automatic wire winding process

- Step 2: Paste Paper Tap 1

After winding the copper wire layers, the jig will be moved by conveyor belt to the automatic tap 1 gluing machine. Here, the paper will be glued onto the jig by a suction cylinder on the robot shaft dipped in methanol solution to create adhesion on the jig, then put on the goods. Then the cylinder is used in combination with the rotating motor shaft to glue the paper layer evenly on the goods with the purpose of preventing unwanted contact between external factors affecting the wrapped copper layer.

- Step 3: Shape the voice coil

The Jig mold will be transported by conveyor belt to the shaping machine to be glued to shape the voice coil copper wire from perpendicular to the jig to coincide with the jig's direction, then the conveyor belt moves to the suction turntable cylinder cluster at the same time the two jigs move to the next conveyor belt and then transfer to the tap2 gluing machine.

- Step 4: Paste the Tap 2 Paper

The tap2 machine will receive and hold the jig and stick the second wire on top so that the paper edge is correct (the wire is also dipped in methanol solution). Then the jig is moved by conveyor belt to the laser embossing machine.

- Step 5: Remove the emay shell

The jig is transported by conveyor belt to the emay peeling machine, which uses a laser to shoot off the insulation layer on the copper wire and the copper layer attached to the previously wrapped adhesive paper, then sends it to the automatic alloy welding machine to weld the copper wire to the copper layer on it. In addition, there is an AI image processing section to check whether the quality of the joint is good or not.

- Step 6: Put the goods into the drying box

The Jig mold will be transported by conveyor belt and moved to the picker machine. This machine is responsible for picking up each Jig mold and then putting it on the conveyor belt of the drying barrel and putting it into the drying barrel to create catalyst temperature conditions for the methanol solution to dry the tape paper layer.

- Step 7: Remove goods from the drying box

After passing through the drying box, the jig will be taken out by a pick-up mechanism and sent through the layout 2 conveyor belt.

Layout 2:

- Step 8: Solder the tinsel wire

The jig will be fed into the Tinsel welder to weld the two wire feed strands (woven fabric with wire) to the weld that has been fired at the emay peeling machine.

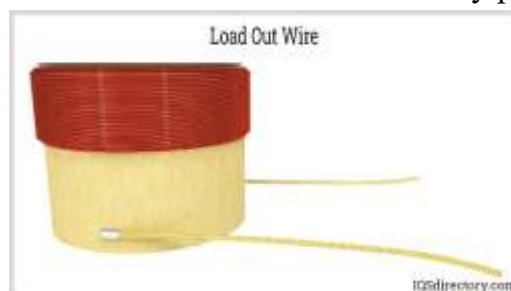


Figure 1.10 Wire-carrying strand welding process

- Step 9: Remove excess copper wire

The jig will be moved to the voice coil machine to remove the excess copper wire using a circular interpolation robot to pluck the excess copper wire.

- Step 10: inject glue into the weld

The jig will be moved to the voice coil glue injection machine at the weld position, then the turntable mechanism will transport the two jigs to the next conveyor to move the two jigs to the opposite conveyor through the redmarking machine to dry the glue.

- Step 11: Put the goods into the redmarking machine

The jig is Redmarked by the machine to mark a different name on the voice coil on the paper layer that has been wrapped on the jig. Then the jig will be picked up by the robot on the chain conveyor and put into the drying box fixed on the chain conveyor to dry the glue layer injected on the jig. Then the jigs on the chain conveyor will be picked up by the robot and punched to obtain the voice coil shell and will be transported on the conveyor through the DCR check machine.

- Step 12:

Jig will be checked by DCR machine to check the resistance of voice coil with Hioki RM3544 machine and the polarity of the coil, if the goods are ok, they will be transported at the output, if the welding error is, the robot will take it off the conveyor belt and remove it.

1.3 Purpose

In the context of the increasingly strong development of the audio equipment manufacturing industry, the demand for high-quality components such as voice coils is also increasing. Voice coils are key components in speakers and audio equipment, playing the role of converting electrical signals into mechanical oscillations to create sound. The technical specifications of voice coils require high precision in each stage of production, especially the process of sticking tape on the coil, to fix the shape, increase mechanical strength and insulation for the product.

Currently, many manufacturing facilities still perform the tape pasting operation manually, leading to many limitations such as: incorrect pasting position, uneven pressure, long operating time and high dependence on worker skills. This not only affects product quality but also reduces production efficiency, especially when scale and output increase.

Faced with increasingly stringent quality requirements, as well as the trend of automation in industrial production, the research and manufacture of an automatic tape-applying machine specifically for voice coils is truly necessary and urgent. This project not only helps improve productivity, accuracy, and stability in production, but also opens up a new direction for optimizing the audio component processing line at factories.

1.4 Outline

In this thesis we will present the following content:

- Chapter 1: The first chapter will present the background and reasons for the topic of designing a tape gluing machine for voice coils - an important component in the field of audio equipment manufacturing. Current production is facing many difficulties in

ensuring the accuracy and stability of the tape gluing operation when performed manually, thereby giving rise to the urgent need for an automated solution. This chapter will also clearly state the objectives of the topic, the scope of the research, the approach, and the overall structure of the thesis, in order to help readers have an overview before going into the next chapters.

- Chapter 2: This chapter focuses on the mechanical structure design process of the tape gluing machine. The content will focus on analyzing the technical requirements of the product, selecting the appropriate design solution, and presenting the main parts of the machine such as the tape gripper, jig turntable, positioning cylinder and tape roller mechanism. In addition, the chapter also mentions technical drawings and 3D models to support the manufacturing process. Building a solid, flexible and optimal mechanical system is an important foundation for the stability and accuracy of the machine's operation.
- Chapter 3: Chapter three will present the content related to the design of the control system for the tape machine, focusing on the programming of Keyence PLC. The content will include the construction of the control algorithm diagram, the selection of suitable hardware such as sensors, pneumatic valves, relays and central controllers, as well as the development of the logic control program for the entire operation cycle of the machine. This chapter also analyzes the safety mechanisms, error handling and operating interface to improve the flexibility and efficiency in actual use.
- Chapter 4: This chapter presents the results obtained after the process of designing, manufacturing and testing the tape machine. The technical parameters, actual performance and efficiency of the machine will be evaluated through specific tests. At the same time, the chapter also compares the manual and automatic tape application methods, thereby clarifying the benefits that the system brings. The strengths, limitations and suggestions for improvement will also be discussed to improve in the next versions.
- Chapter 5: The final chapter summarizes all the content presented in the thesis, emphasizing the achievements, especially the application of theoretical knowledge into practice to successfully design an automatic tape-applying system. At the same time, this chapter also highlights the potential for practical application of the machine in the industrial environment, as well as future development orientation. The final part is a thank you to Foster Company, the instructors and individuals who supported throughout the thesis process.

CHAPTER 2: Structural Design

2.1 Design requirements and important technical specifications

Regarding materials, the required materials are high strength, light weight and good abrasion resistance.

Regarding the structure, the machine design requires compactness, simple structure and ease of assembly and maintenance.

Regarding tape gluing speed, the machine speed does not require too high, but must ensure gluing 2 products within 15-20 seconds, to ensure the operating time of the next machines and ensure the time requirement to create a complete product.

In terms of control, because the tape gluing machine operates on a simple principle but requires high precision, the control system requires a simple design that is easy for workers to monitor and operate.

2.1.1 Accuracy requirements

The tape gluing machine is required to have a simple design because the principle of gluing operation is quite simple, but the accuracy requirement must be high because the tape gluing step is the first step to create a complete product. If the tape gluing does not ensure the accuracy requirement, it will lead to errors in the following steps, leading to the product being defective.

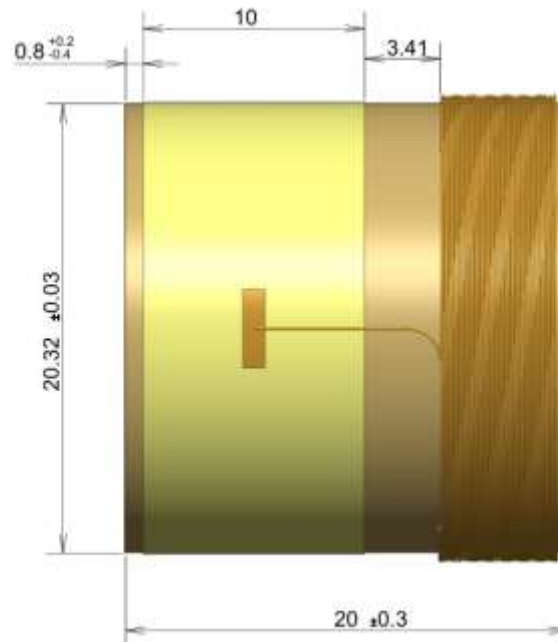


Figure 2.1 Tape position accuracy requirements

Tape with dimensions of 10mm wide, 75mm long and 0.08mm thick. Technical requirements for tape placement are the distance from the outer edge of the tape to the outer edge of the Bobbin is 0.8mm with a tolerance of -0.4mm to 0.2mm. And the distance from the inner edge of the tape to the position of the voicol wire is 3.41mm.

In addition, on the tape there are two black line marking positions, these two positions must coincide to ensure that the voicol wire will be in the middle of the soldering contact on the tape.

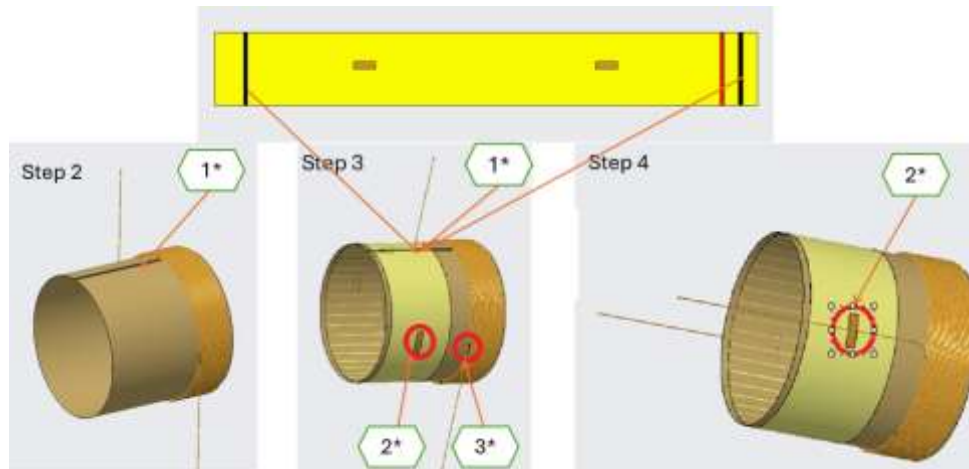


Figure 2.2 Tape placement requirements

The tape pasting step that the machine performs is step 3 and the position of the black line on the tape after pasting must coincide at (1*) to ensure that the voicol wire will be in the middle of the welding point at position (2*).

2.1.2 Speed requirement.

According to the calculation, the speed of the voicol wire winding machine in step 1 combined with the worker putting the product into the production line is on average from 5-7 seconds per product. From there, the time for the machine to finish pasting a required tape is from 5-6 seconds to ensure the time to create a finished product for the line.

To ensure execution time and at the same time meet high accuracy, the design requirement must minimize the execution structure to meet the execution time.

2.1.3 Operating and maintainability.

The operability of the machine design and control system for the machine must be simple, easy to monitor machine operation and easy to handle in case of errors.

Regarding maintenance, the maintenance and replacement requirements must be quick and easy because when a tape machine error occurs, the entire production line will have to stop working, leading to the system not achieving its working capacity. Therefore, the design of the mechanism must ensure that the assembly and replacement of the mechanisms are simple and easy.

2.2 Design solutions

To solve the problem of taping and ensure the requirements, it is necessary to propose design solutions for the following problems:

- Tape feeding problem for the gluing machine.
- The problem of moving the tape from the holder to the correct position to be pasted.
- Tape problem.

2.2.1 Tape supply problem solution

To solve the problem of providing tape groups based on the shape and size of the tape, a design solution will be provided.

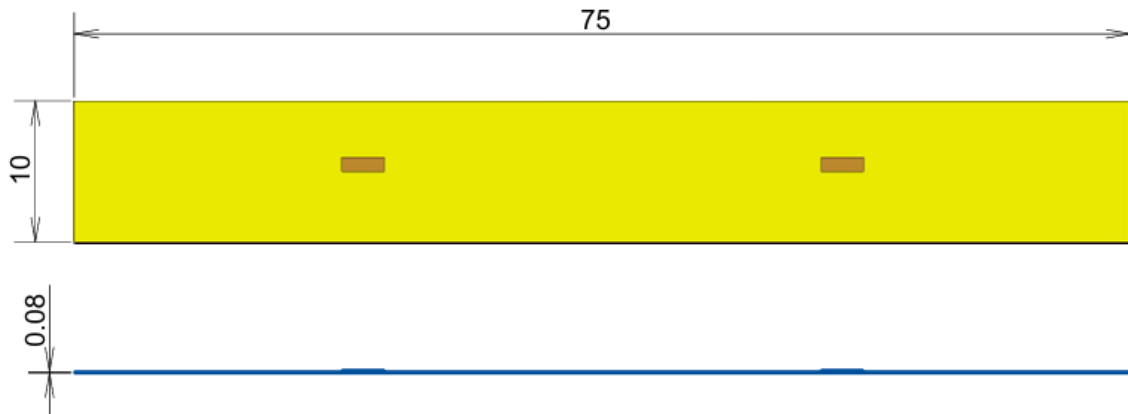


Figure 2.3 Tape size

The tape is rectangular in shape with a length of 75mm, a width of 10mm and a thickness of 0.08mm. Because the tape is very thin, the problem of supplying tape to the machine is that the group has come up with solutions to design a tape box with many compartments to hold the tape. And because before sticking the tape, the tape needs to be dipped in methanol solvent, the cluster will be designed including the tape box and the solvent box right above to ensure a simple structure and shorten the implementation time.

- Design solution 1

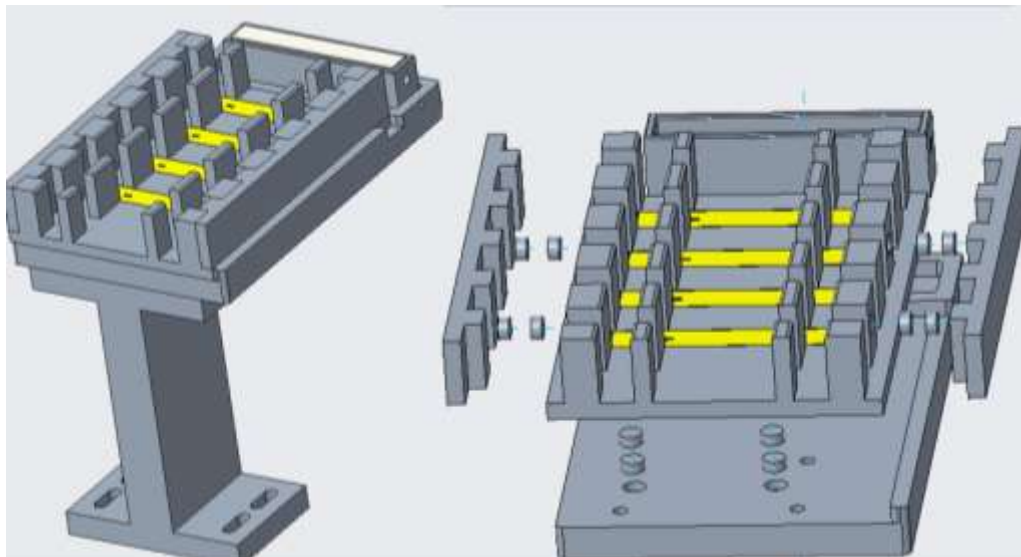


Figure 2.4 Tape box design 1

With the first design solution, the tape box design team consists of 5 compartments with each compartment height of 20mm, and tape thickness of 0.08mm, from which we calculate that each compartment can hold 200 tapes and a total of 5 compartments can hold 1000 tapes each time.

The tape box will be designed separately, attached to the base by magnets, and the walls of the tape box are also designed to be assembled together by magnets, making it easy to disassemble and add more tape when it runs out.

- Design solution 2:

With the first design solution, the tape supply problem was solved with a simple design mechanism. But after analysis, the group still proposed the second design method to ensure that the tape when taken out of the box would be flat and straight before being brought to the gluing position to meet the requirements.

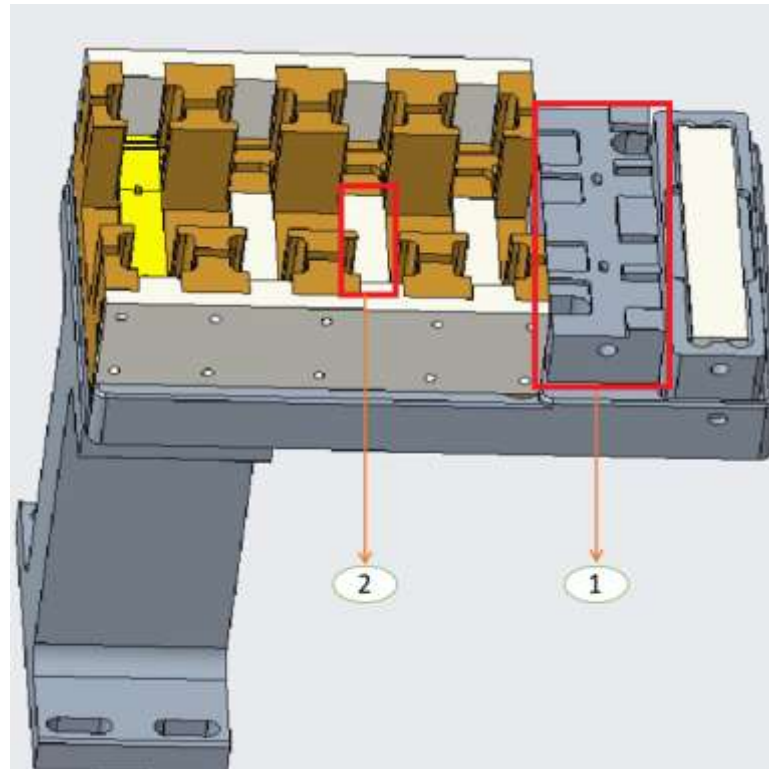


Figure 2.5 Tape box design 2

Regarding design solution 2 for the tape leveling problem, the team designed an additional detail [1] to flatten the tape after the tape removal mechanism is removed from the container to ensure that when the tape is brought to the sticking position, it will be straight and flat.

In addition, the group also designed detail number [2]. This detail is located at the bottom of each tape compartment with a spring attached to create elasticity to make it easy to take the tape out of the box, especially the tapes at the bottom of the compartment.

2.2.2 Solution to bring tape to the position to be pasted

❖ Tape take-up mechanism.

Regarding the problem of moving the tape from the container to the position where it needs to be pasted, the group proposed a solution by designing a suction mechanism. Because the tape is very thin, solutions such as tweezers or clamps are not feasible. Therefore, the group proposed a suction head design with the following designs:

- Design solution 1

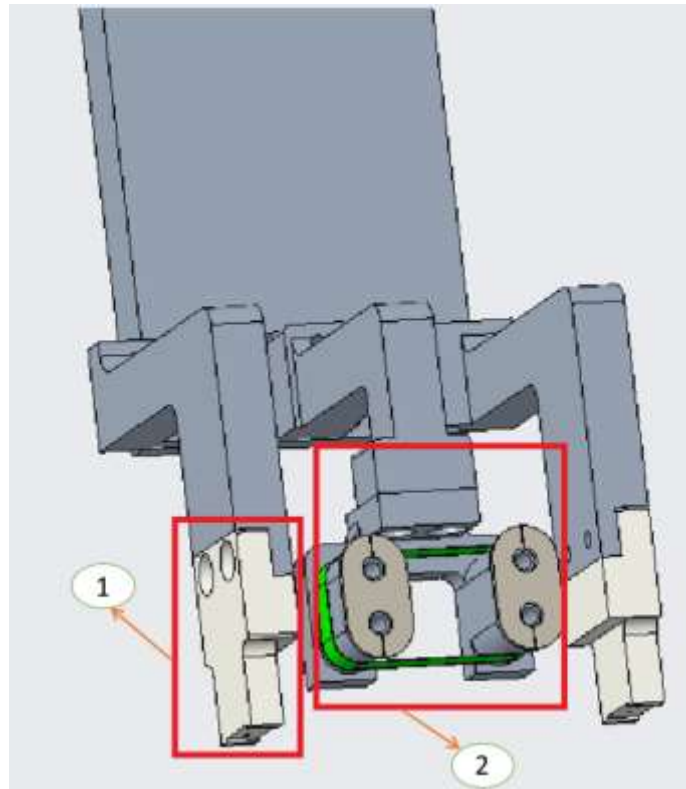


Figure 2.6 Tape suction mechanism design 1

Regarding the design solution, a group designed a tape suction mechanism with two suction heads [1]. With two suction heads, the tape will be sucked straighter and easier than with one suction head.

In addition, the group also designed a mechanism [2] with an elastic band attached, and when the suction head brings the tape to the position that needs to be glued, the mechanism [2] with the elastic band will press down to fix the tape in the position where the suction head is placed.

- Design Solution 2

With the design in solution 1, the requirement of simple structure and the ability to suck tape is ensured, but to avoid the case of sucking during the methanol dipping process, the tape falls due to the narrow suction area and very thin tape and to be able to use the machine for products with tape length longer than 75mm. Therefore, the group proposed design solution 2.

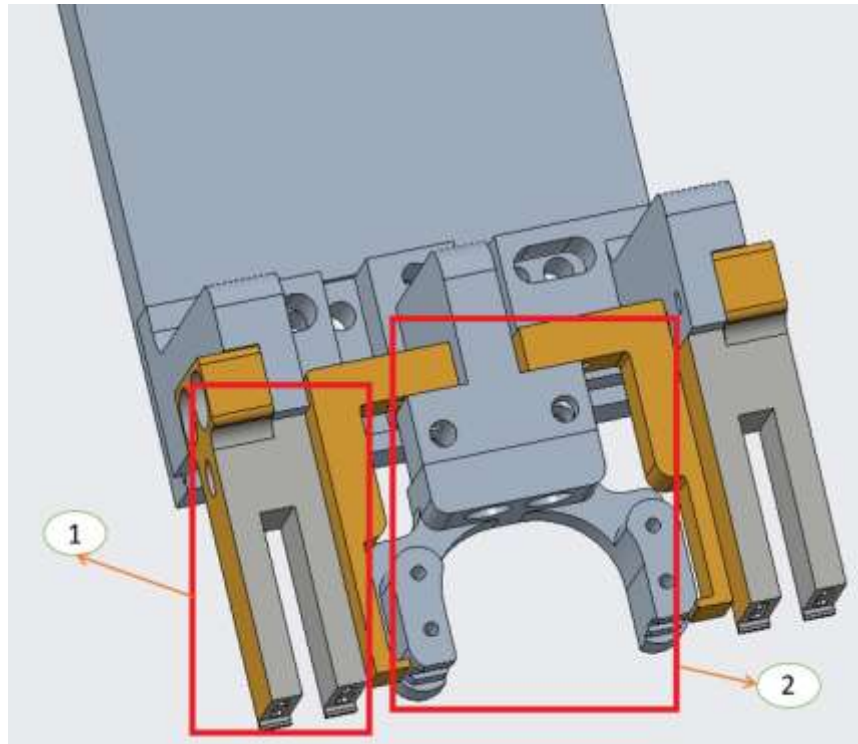


Figure 2.7 Tape suction mechanism design 2

Regarding this design solution 2, the suction head [1] has been changed, each side has been transformed into two suction heads to increase the contact area, making the tape suction process easier and more secure.

In addition, in the mechanism [2] to press the tape firmly into the position to be pasted, the group designed additional details to help the mechanism support flattening the tape when sucking the tape.

❖ Tape movement mechanism

Regarding the tape moving mechanism to ensure the high precision required by the product, the group chose the robot cluster mechanism.

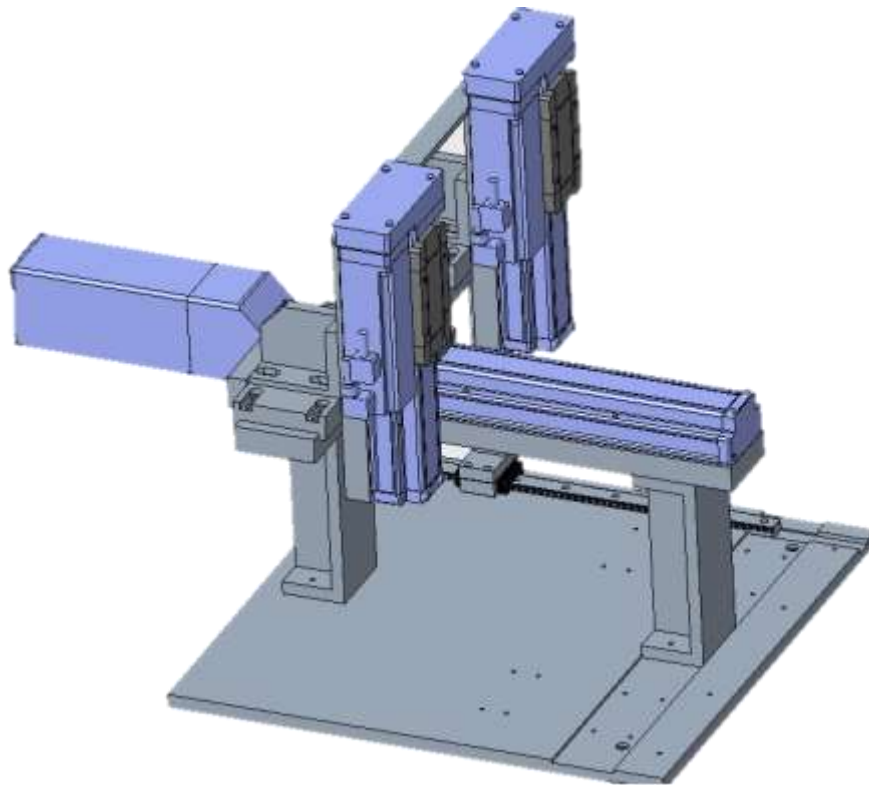


Figure 2.8 Tape suction mechanism design 2

Because of the need to take the tape and move to the position that needs to be pasted, the group chose a robot that moves along the Y axis to move after sucking from the box to the pasting position.

And two robots move along the Z axis to pick up the tape from the box and place the tape in the position that needs to be pasted. Using two robots to ensure that one move can bring two tapes to the position that needs to be pasted to ensure the execution time.

2.2.3 Tape paste solution

For the tape solution, the design idea proposed by the group is based on the principle of manually applying tape around a circle so that the tape is applied evenly around the area that needs to be applied.

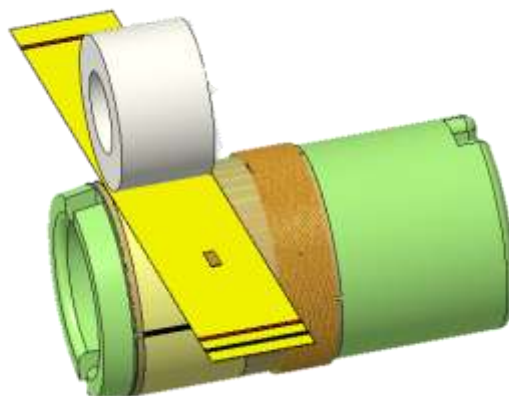


Figure 2.9 Idea of tape

From the shape of the product fixture, we can visualize how to tape around the product by creating two cylinder movements to stick the tape to the designated position. From that idea, the team came up with the following design options:

- Design solution 1

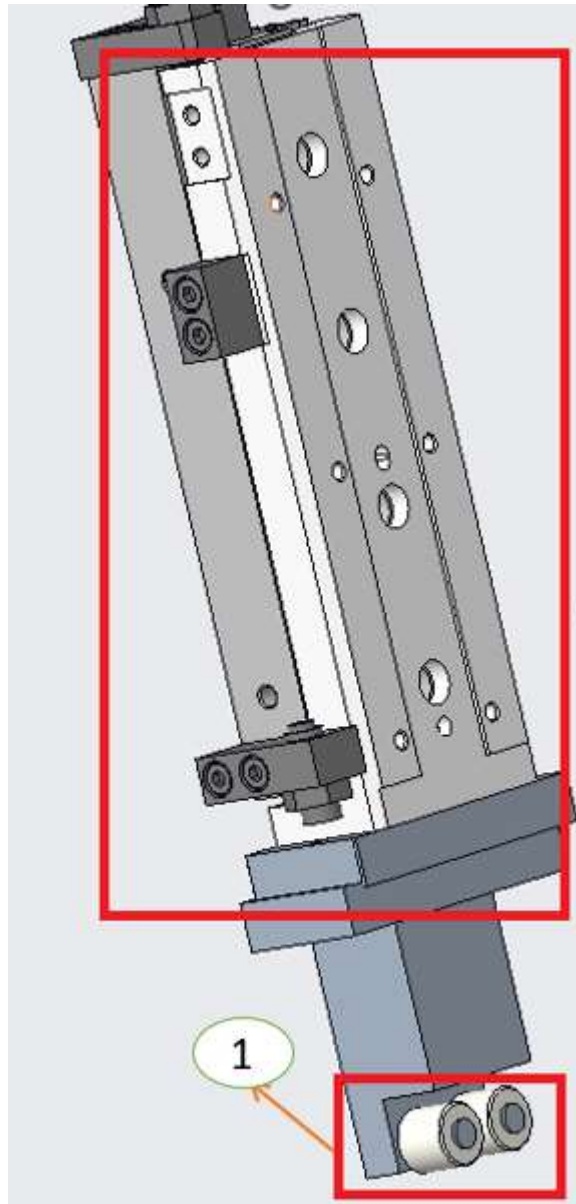


Figure 2.10 Tape gluing mechanism design 1

With the idea of pasting tape as above, the group designed a simple tape pasting mechanism consisting of a cylinder pushing down to create pressure and a mechanism consisting of two rollers moving around the tangent of the product fixture to past the tape.

- Design Solution 2

Regarding design option 1, a simple mechanism was designed that could stick the tape, but to ensure the accuracy and the ability to stick the tape evenly, whether or not the accuracy of the product is achieved depends mainly on this tape sticking mechanism. Therefore, the group came up with design option 2.

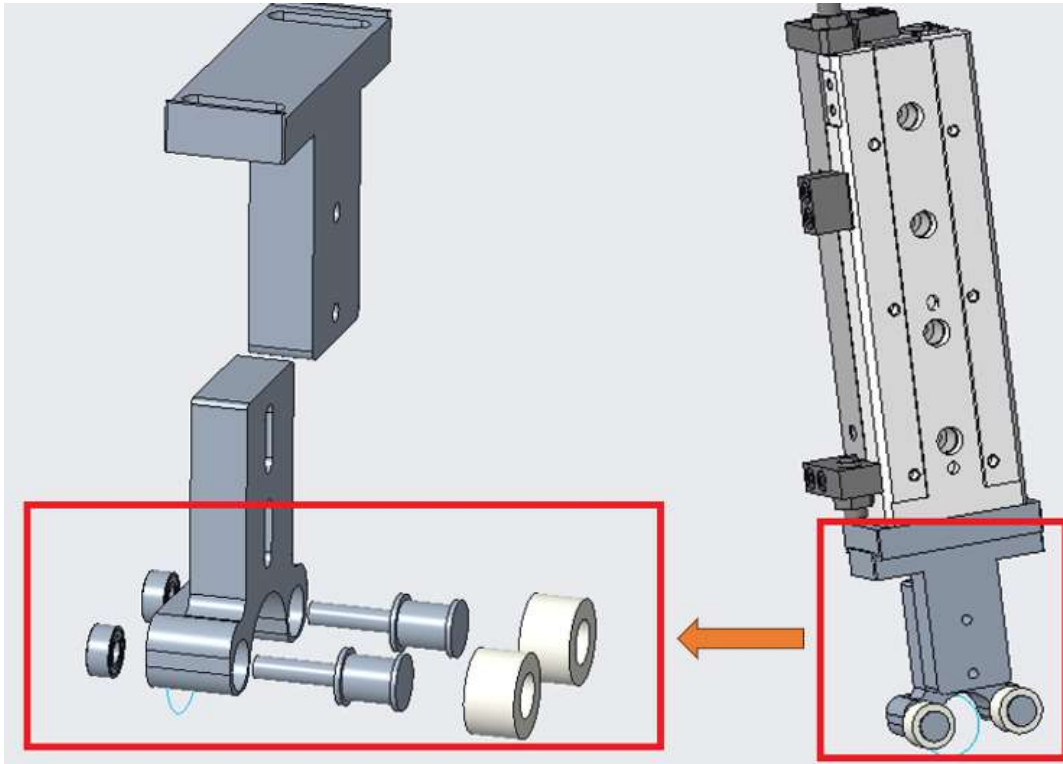


Figure 2.11 Tape gluing mechanism design 2

Compared with design option 1, because the design group head moves the two rollers around the axis, the movement is loosely mounted, so there is friction, making the gluing process inaccurate, and the contact area between the two rollers is not enough, so it is easy to cause gluing errors.

To overcome the disadvantages of design 1, design 2 has widened the distance between the two rollers to better fit the Jig and placed the square on the two roller shafts of the roller, thereby creating easy movement during the gluing process and increasing accuracy.

- Design Option 3

For the product that the group was assigned to design, design option 2 has responded relatively well and stably. However, if the voicol product code has a smaller or larger size, there will be disadvantages, so the group has come up with design option 3.

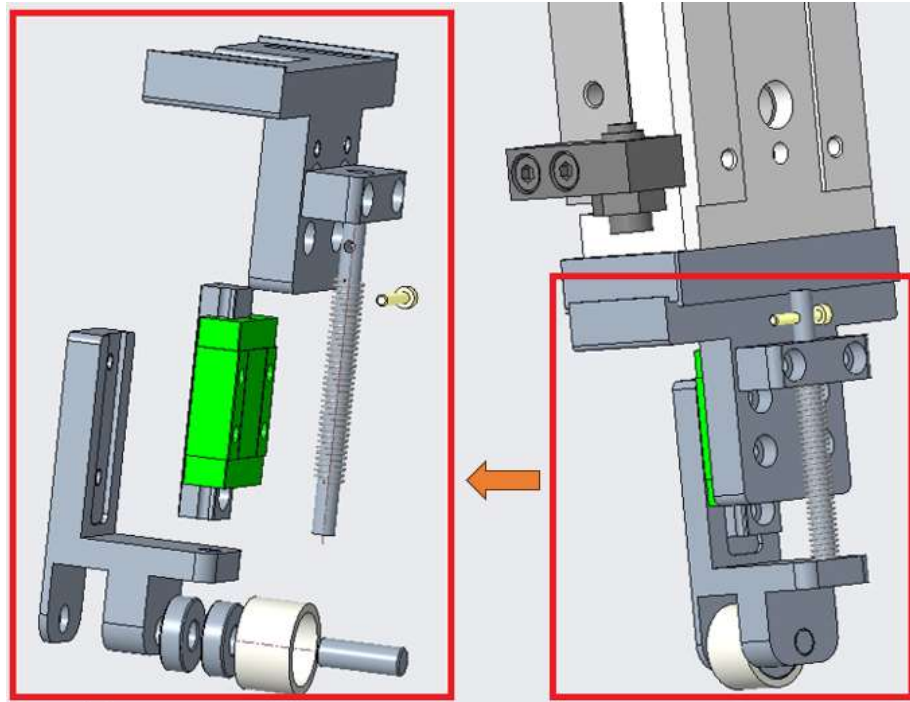


Figure 2.12 Tape gluing mechanism design 2

Design option 3 has changed from two roller heads for gluing to one roller head that moves tangentially to the Jig for gluing tape, and moves around a ball bearing axis. This one roller head option can be applied to many product codes with different sizes.

In addition, this design also uses slide rails and springs to create movement to help press better depending on the deviation of the cylinder stroke and help press better.

2.3 Calculation and equipment selection

2.3.1 Select z-axis robot

To select the robot axis for the z axis, we need to estimate the total load that the robot axis needs to bear to select the appropriate motor and calculate the travel distance to select the appropriate robot travel.

- ❖ Select robot axis travel.

From the machine installation space and machine model design, the group calculated that the robot axis must move to suck the tape and place the tape in the position to be pasted, which is about 75mm.

- ❖ Select the motor for the robot axis.

To choose the motor for the Z-axis Robot, we first need to estimate the load that the axis needs to carry. The Z-axis will carry a suction mechanism machined from A6061 material, the estimated mass of the suction mechanism is about 3kg.

- Suppose:
 - Lifting load: $m = 3 \text{ kg}$
 - Lifting/lowering time of 80 mm stroke: $t = 0.4 \text{ s}$
 - Acceleration: $a = 0.5g \approx 4.905 \text{ m/s}^2$
 - Maximum speed: $v = 0.1 \text{ m/s}$ Load safety factor: 30%

- Force calculation.

Force due to gravity:

$$F_g = m * g = 3 * 9.8 = 29.4 \text{ N}$$

Force due to acceleration:

$$F_a = m * a = 1 * 4.905 = 14.715 \text{ N}$$

Total force without safety factor:

$$F = F_g + F_a = 29.4 + 14.715 = 44.115 \text{ N}$$

Force with safety factor:

$$F_{safe} = 29.4 * 1.3 = 57.3495 \text{ N}$$

- Calculate torque

Recipe:

$$T = \frac{F * p}{2\pi * \eta}$$

In there:

p: Screw thread pitch

η : Efficiency of screw mechanism

We have: $F = 57.3495 \text{ N}$, $p = 0.006 \text{ m}$, $\eta = 0.85$

$$T = \frac{F * p}{2\pi * \eta} = \frac{57.3495 * 0.006}{2\pi * 0.85} = 0.064 \text{ Nm}$$

- Calculate the required motor rotation speed

Recipe:

$$v = \frac{n * p}{60}$$

Hence: $n = \frac{v * 60}{p}$

Sole iv = 0.1 m/s, $p = 0.006 \text{ m}$

We have:

$$n = \frac{v * 60}{p} = \frac{0.1 * 60}{0.006} = 1000 \text{ rpm}$$

⇒ With the robot travel that we have calculated combined with the calculated load parameters as above, we choose the R5 motor, with the SMC screw mechanism with the code LEFS25V6H-100BK-R5M21.

Servo R5 (200W) has parameters:

- Rated moment: 0.637 Nm
- Maximum torque: 1.91 Nm

- Rated speed: 3000 rpm
- Compare:
 - Required torque: $0.064 \text{ Nm} < 0.637 \text{ Nm}$ (choose extra to be able to use for other machines later)
 - Required speed: $1000 \text{ rpm} < 3000 \text{ rpm}$
 - Anti-slip brake required, suitable for Z axis requirements
 - Required stroke $75 \text{ mm} < 100\text{mm}$ (suitable for required stroke)

From the load capacity and travel, we choose the robot shaft code LEFS25V6H-100BK-R5M21 of SMC to fully meet the requirements. Smooth operation, safe and has a lot of excess load.

- Robot axis code LEFS25V6H-100BK-R5M21 of SMC.

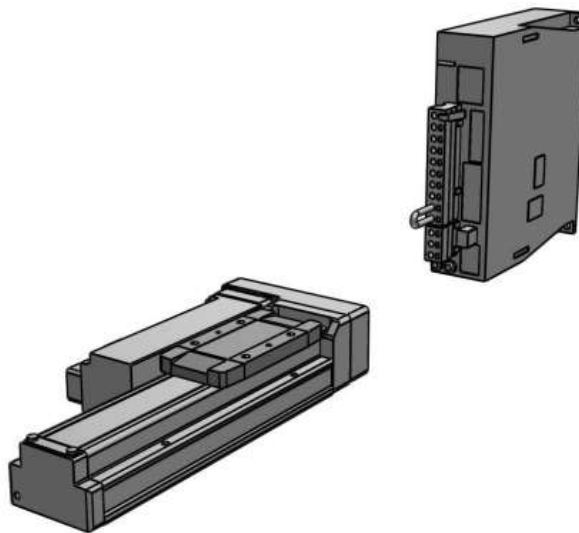


Figure 2.13 3D image of robot axis

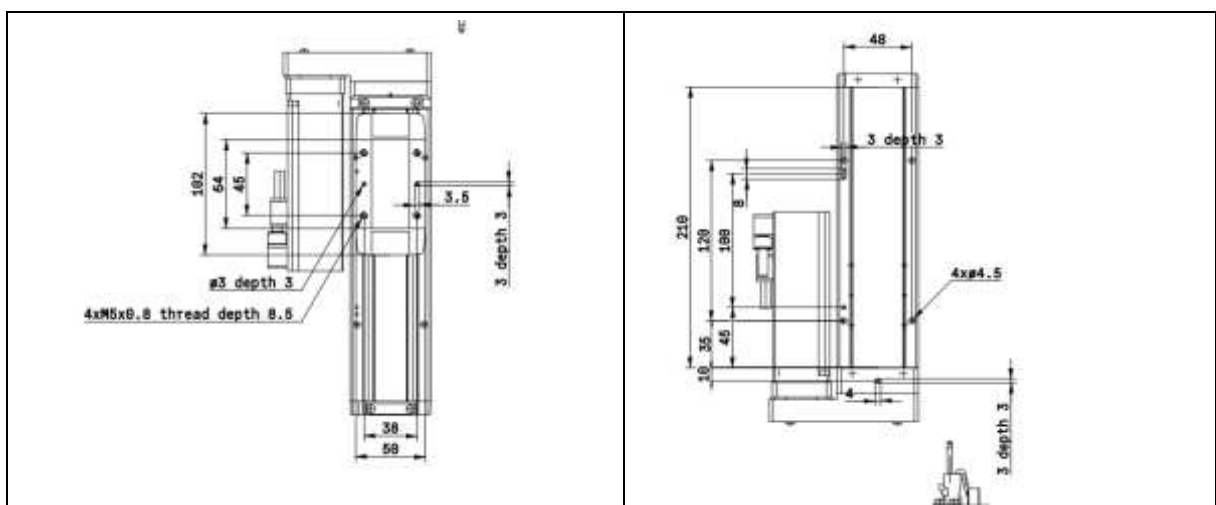


Figure 2.14 Dimensions LEFS25V6H-100BK-R5M21

- Specifications LEFS25V6H-100BK-R5M21.

Specifications: LEFS Series Electric Actuator/Slider Type Ball Screw Drive MECHATROLINK Compatible AC Driver Servo Motor

Series LEFS Step Motor (Servo/24 VDC) Servo Motor (24 VDC)

- Max. work load: 65 kg
- Positioning repeatability: ±0.02 mm
- Clean specification: Complies with ISO Class 4 (ISO14644-1) (11-LEFS only)
- Compatible controllers: JXC51, JXC61, JXCE1, JXC91, JXCP1, JXCD1, JXCL1, JXCM1, LECA6, LECP1, LECPA, LECP6 (Manufacture Discontinued), LECPMJ (Manufacture Discontinued)

Series LEFS AC Servo Motor

- High output motor (100/200/400 W)
- Improved high speed transfer ability
- High acceleration/deceleration (20000mm/S²)
- Pulse input type
- With internal absolute encoder (For the LECSB/C/S)
- Positioning repeatability: ±0.01 mm (High precision type)
- Clean specification: Complies with ISO Class 4 (ISO14644-1) (11-LEFS only)
- Compatible drivers: LECSA, LECSB(-T), LECS(-T), LECS, LECS-S (Manufacture Discontinued), LECS(-S) (Manufacture Discontinued), LECS(-S) (Manufacture Discontinued)

Field	Value	Value Details
Accuracy	-	Basic
Size	25	25
Motor Mounting Position	R	Right Side Parallel
Motor Type	V6	AC Servo Motor(Absolute Encoder), Output 100W, Actuator Size 25 mm
Lead	H	Size25:20 mm, Size32:24 mm, Size40:30 mm
Stroke	100	Stroke 100 mm
Motor Option	B	With Lock
Auto Switch Mounting Bracket	-	None
Grease Application (Seal Band Part)	-	With
Positioning Pin Hole	K	Body Bottom 2 Locations
Cable Type	R	Robotic Cable(Flexible Cable)
Cable Length	5	5 m
Driver Type	M2	LECYM2-V, Power Supply Voltage 200V To 230V
I/O Cable Length	1	1.5 m

Figure 2.15 Robot axis specifications LEFS25V6H-100BK-R5M21

2.3.2 Select the y-axis robot

Similarly, to choose the robot axis for the y-axis, we need to estimate the total load that the robot axis needs to bear to choose the appropriate motor and calculate the travel distance to choose the appropriate robot travel.

- ❖ Select robot axis travel.

From the machine installation layout and machine model design, the group calculated the required y-axis travel distance to be 215mm.

- ❖ Select the motor for the robot axis.

Similar to the z-axis, the load that the y-axis needs to carry is the entire mass of the two robot axes, which are the tape suction machine, as well as the mass of the z-axis robot fixture. The mass on the two z-axis is about 8kg for each axis, and the fixture is made of A6061 material, about 4kg. The total estimated mass is 20kg.

- Suppose:

Lifting load: $m \approx 20 \text{ kg}$

Lifting/lowering time of 200 mm stroke: $t = 0.6 \text{ s}$

Acceleration: $a = 0.4g \approx 3.924 \text{ m/s}^2$

Maximum speed: $v = 0.25 \text{ m/s}$

Load safety factor: 25%

- Required force

Force due to gravity/negligible friction in horizontal direction

Force due to acceleration:

$$F_a = m * a = 20 * 3.924 = 78.48 \text{ N}$$

Force with safety factor:

$$F_{safe} = 78.48 * 1.25 = 98.1 \text{ N}$$

- Calculate the required torque

Recipe:

$$T = \frac{F * p}{2\pi * \eta}$$

In there:

- p: Screw thread pitch
- η : Efficiency of the screw mechanism

We have: $F = 98.1 \text{ N}$, $p = 0.007 \text{ m}$, $\eta = 0.85$

$$T = \frac{F * p}{2\pi * \eta} = \frac{98.1 * 0.007}{2\pi * 0.85} = 0.128 \text{ Nm}$$

- Calculate the required rotational speed of the motor

Recipe:

$$v = \frac{n * p}{60}$$

Hence:

$$n = \frac{v * 60}{p}$$

Solve $v = 0.25 \text{ m/s}$, $p = 0.007 \text{ m}$

We have:

$$n = \frac{v * 60}{p} = \frac{0.25 * 60}{0.007} = 2143 \text{ rpm}$$

⇒ With the robot travel that we have calculated combined with the calculated load parameters as above, we choose the R5 motor, with the SMC screw mechanism with the code LEFS25RV6H-250BK-R5M21.

- Servo R5 (200W) has parameters:

- Rated moment: 0.637 Nm
- Maximum torque: 1.91 Nm
- Rated speed: 3000 rpm

- Compare:

- Required torque: $0.128 \text{ Nm} < 0.637 \text{ Nm}$ (choose excess to ensure safety and can be used for future machines)
- Required speed: $2143 \text{ rpm} < 3000 \text{ rpm}$

- Required stroke 215 mm < 250mm (suitable for required stroke)
- Robot axis code LEFS25RV6H-250BK-R5M21 of SMC.

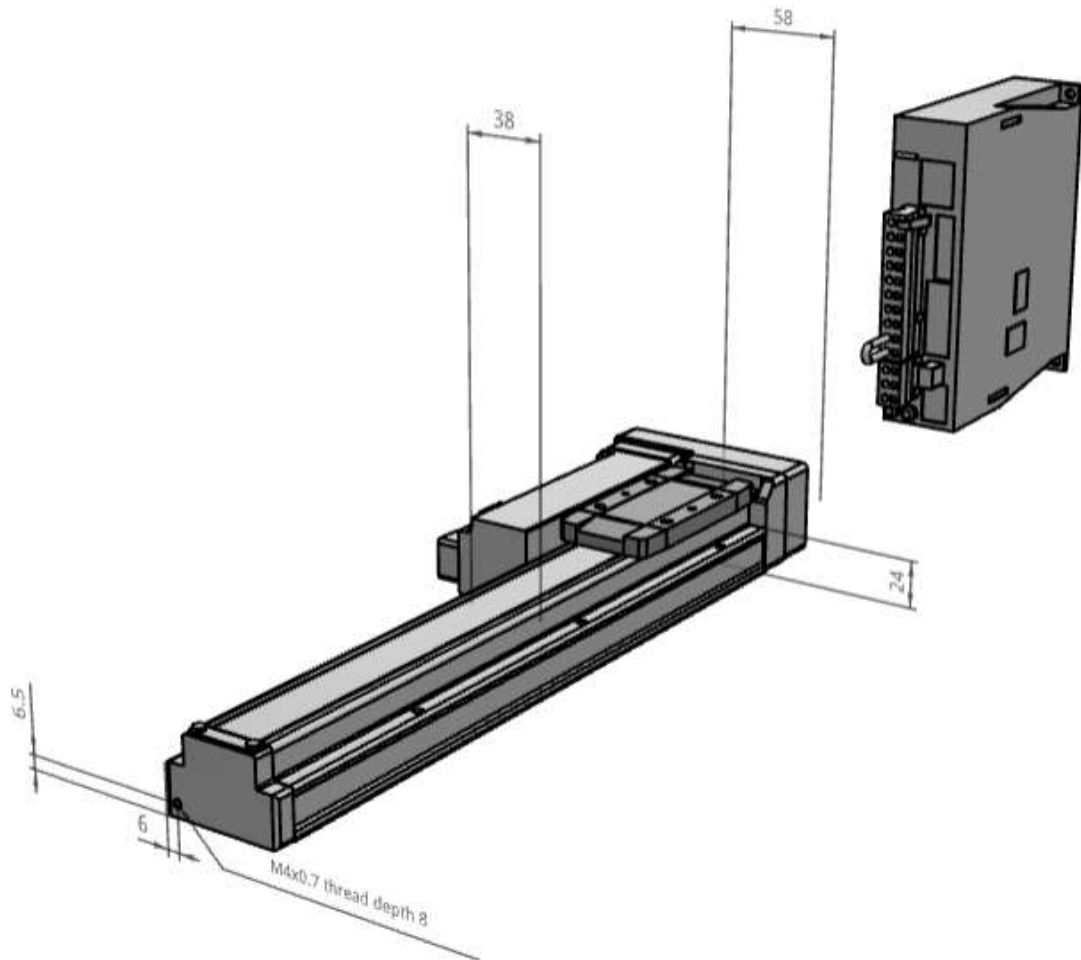


Figure 2.16 3D image of robot axis

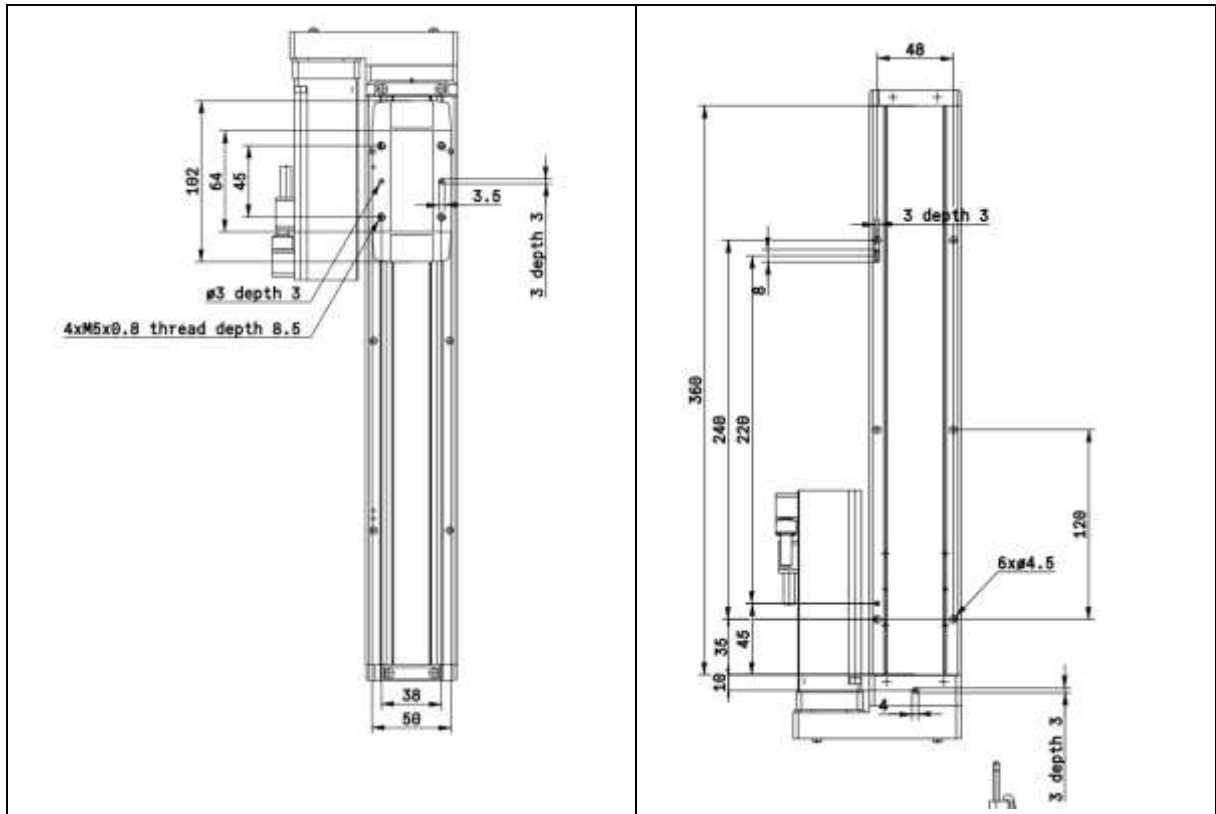


Figure 2.17 Dimensions of robot axis LEFS25RV6H-250BK-R5M21

- Specifications LEFS25V6H-100BK-R5M21.

Specifications: LEFS Series Electric Actuator/Slider Type Ball Screw Drive MECHATROLINK Compatible AC Driver Servo Motor

Series LEFS Step Motor (Servo/24 VDC) Servo Motor (24 VDC)

- Max. work load: 65 kg
- Positioning repeatability: ±0.02 mm
- Clean specification: Complies with ISO Class 4 (ISO14644-1) (11-LEFS only)
- Compatible controllers: JXC51, JXC61, JXC61, JXC91, JXCP1, JXC01, JXCL1, JXCM1, LECA6, LECPI, LECPA, LECP6 (Manufacture Discontinued), LECPMJ (Manufacture Discontinued)

Series LEFS AC Servo Motor

- High output motor (100/200/400 W)
- Improved high speed transfer ability
- High acceleration/deceleration (20000mm/s²)
- Pulse input type
- With internal absolute encoder (For the LECSB/C/S)
- Positioning repeatability: ±0.01 mm (High precision type)
- Clean specification: Complies with ISO Class 4 (ISO14644-1) (11-LEFS only)
- Compatible drivers: LECSA, LECSB(-T), LECSC(-T), LECS5, LECS5-T, LECSN-T, LECSN-T, LECSB-S (Manufacture Discontinued), LECSC-S (Manufacture Discontinued), LECS5-S (Manufacture Discontinued)

Field	Value	Value Details
Accuracy	-	Basic
Size	25	25
Motor Mounting Position	R	Right Side Parallel
Motor Type	VS	AC Servo Motor(Absolute Encoder), Output 100W, Actuator Size 25 mm
Load	H	Size25:20 mm, Size32:24 mm, Size40:30 mm
Stroke	250	Stroke 250 mm
Motor Option	0	With Lock
Auto Switch Mounting Bracket	-	None
Groove Application (Seal Band Part)	-	With
Positioning Pin Hole	X	Body Bottom 2 Locations
Cable Type	R	Robotics Cable(Leadto Cable)
Cable Length	5	5 m
Driver Type	M3	LECM3 X, Power Supply Voltage 200V To 230V
UD Cable Length	1	1.5 m

Figure 2.18 Specifications of the y-axis

2.3.3 Select the tape pressure cylinder.

With the initial design idea, the cylinder required a stroke of 70mm. After many tests, the team concluded that the optimal cylinder pressing force on the tape was 5-7N with a pneumatic pressure of 1bar. From there, we calculated the required technical parameters as follows:

- The pressure of compressed air is:

$$P = 1 \times 10^5 = 100000 \text{ (pa)}$$

- The area of the piston face is:

$$A = \frac{F}{P} = \frac{7}{100000} = 7 \times 10^{-5} \text{ (m}^2\text{)}$$

- Because the area of the piston surface is circular, we have:

$$A = \frac{\pi D^2}{4} \Rightarrow D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4 \times 7 \times 10^{-5}}{3.14}} = 0,0094 \text{ (m)}$$

$$D = 0.0094 \times 100 = 0.94 \text{ (mm)}$$

- Choose safety factor as 2:

$$D = 0.94 \times 2 = 1.88 \text{ (mm)}$$

⇒ We see that the diameter of the cylinder needed to press the tape is small because the pressing force does not need to be too large. Therefore, we only need to choose a cylinder with a stroke suitable for the mechanical structure and ensure neatness to avoid making the machine cumbersome. Therefore, the group chooses a double cylinder with the code MSX12-75A of SMC.

- Cylinder MSX12-75A.



Figure 2.19 Cylinder MSX12-75A

- Technical specifications of cylinder MSX12-75A

Type	L-Shaped Table Type	Stroke(mm)	75
Table Material	[Aluminum] Aluminum Alloy	Max. Load Mass (Horizontal Mounting)(kg)	1~4.9
Max. Load Mass(kg)	2	Table Size: Length L(mm)	149
Cylinder I.D.(Ø)	12	Environment	General Purpose
Table Surface Treatment	[Anodize] Hard Anodize	Guide Type	[Rolling Guide] Cross Roller Guide Shape
Table Size: Width W(mm)	50	Table Size: Height H(mm)	32
Port Screw Type	M screw	Cushion	Rubber cushion
Adjuster Option	Dual-end adjuster	Function Option	Standard
Specifications	Magnet built-in	Auto Switches	None
Lead Wire Length(m)	-	Lead Wire Connector	None
The number of the switches	-	Custom-made Specifications	0.15 to 0.7
Made-to-order	None	-	-

Figure 2.20 technical parameters of MSX12-75A cylinder

2.3.4 Select Jig positioning cylinder.

With the Jig positioning cylinder, the only requirement for cylinder stroke as designed is 25-30mm, and the requirement for compactness and stability, the group chose the double cylinder code MXS12-30AS of SMC.

- Cylinder MXS12-30AS.



Figure 2.21 Cylinder MXS12-30AS.

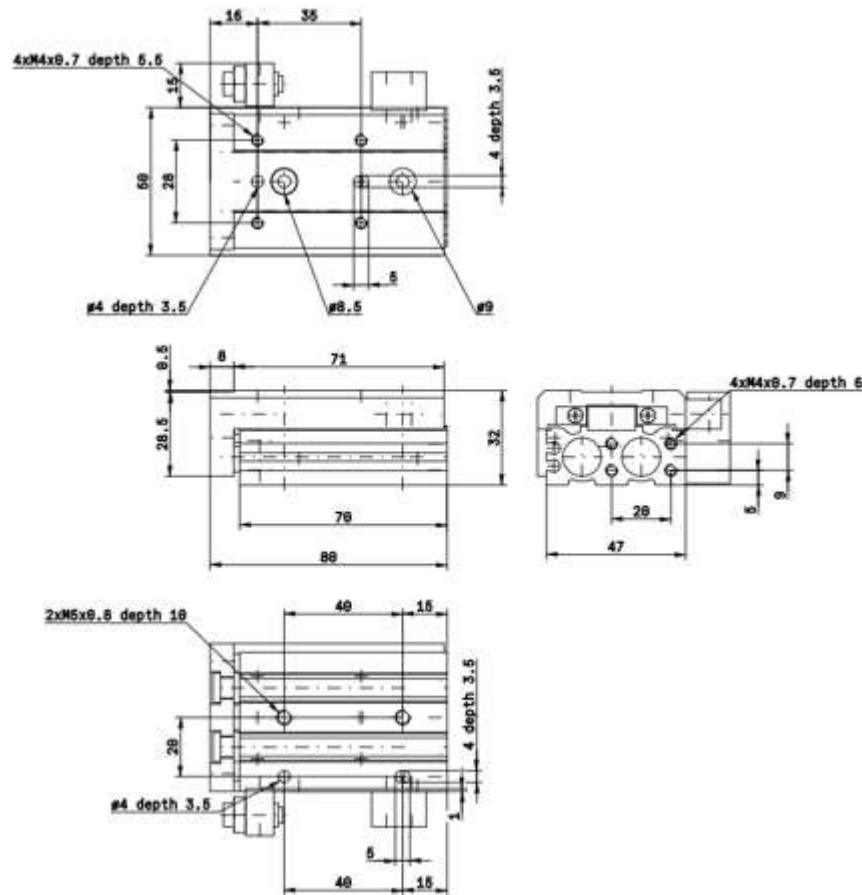


Figure 2.22 MXS12-30AS cylinder dimensions.

- MXS12-30AS cylinder specifications.

Specifications: MXS Series Air Slide Table

- Integrated with a worktable in a compact manner
- An air slide table that is ideal for precision assembly work
- High rigidity and high accuracy
- A smooth movement without looseness has been achieved through the adoption of a cross roller guide
- Compact and lightweight
- Provides twice the output of a conventional cylinder through the adoption of the dual rod function

Field	Value	Value Details
Bore Size	12	Bore Size 12 mm
Port Thread Type	-	M Thread(Φ6-Φ16), Rc(Φ20-Φ25)
Cylinder Stroke	30	Standard Stroke 30 mm
Adjuster Option	AS	Extension end adjuster
Functional Option	-	Standard
Auto Switch	-	Without Auto Switch
Number Of Auto Switches	-	2 pcs. Or None
Made To Order	-	Standard

Figure 2.23 Technical specifications of cylinder MXS12-30AS

2.3. 5 Select Mold positioning cylinder.

With the Mold positioning cylinder, the cylinder stroke requirement as designed is only 25-30mm, and the requirement is compact and stable, so the group chooses a single cylinder with slide rail code MHX16-30Z. by Misumi.

- MHX16-30Z cylinder.



Figure 2.24 MHX16-30Z cylinder.

- MHX16-30Z cylinder specifications.

Type	L-Shaped Table Type	Stroke	30
Table Material	[Aluminum] Aluminum Alloy	Table Size: Length L	70
Cylinder I.D.	16	Environment	General Purpose
Table Surface Treatment	[Anodize] Hard Anodize	Guide Type	[Rolling Guide] Linear guide type
Table Size: Width W	24	Table Size: Height H	53.5
Table Parallelism	50	Port Screw Type	M screw
Cushion	Rubber cushions on both sides	Specifications	Magnet built-in
Auto Switches	None	Lead Wire Length	-
Lead Wire Connector	None	Custom-made Specifications	0.06 to 0.7
Custom-made	-	Made-to-order	None

Figure 2.25 Technical specifications of MHX16-30Z cylinder.

2.3.6 Motor selection for mold positioning cluster.

The mold positioning motor has two main tasks: to position the Jig and after positioning, it will rotate back and forth to stick the tape onto the voicoil surface.

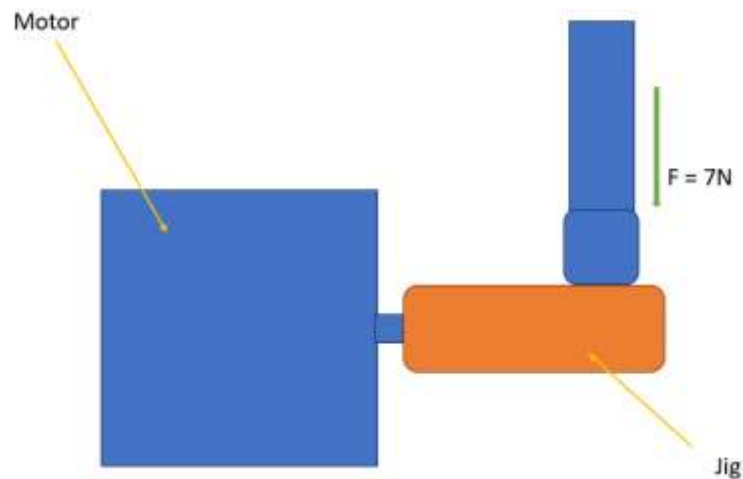


Figure 2.26 Simulation of tape pasting operation

Looking at the illustration, we can see that the force exerted by the press mechanism will be on the plane passing through the center of the shaft, so there will be no torque here. For the motor to rotate, the motor's torque only needs to overcome the initial frictional force of the press assembly. So the motor will be selected as follows:

- The frictional force that the pressing mechanism exerts on the Jig is:

$$F_{ms} = \mu F = 0.3 \times 7 = 2.1 \text{ (N)}$$

Therefore, it is necessary to choose a motor with a static torque greater than 2.1N and must have an encoder to ensure accurate rotation angle. Here, the group chooses the Nema 17 motor with code JK42HS28-0504

- Nema 17 motor specifications code JK42HS28-0504

Mẫu số	Góc bước	Chiều dài động cơ	Hiện hành /Giai đoạn	Sức cản /Giai đoạn	Điện cảm /Giai đoạn	Giữ mô-men xoắn	Số khách hàng tiềm năng	Mô-men xoắn phát hiện	Quần tính rôto	Khối lượng
	(°)	(L) mm	A	Ω	mH	kg.cm	Không.	g.cm	g.cm	Kilôgam
JK42HS25-0404	1,8	25	0,4	24	36	1,8	4	75	20	0,15
JK42HS28-0504	1,8	28	0,5	20	21	1,5	4	85	24	0,22
JK42HS34-1334	1,8	34	1,33	2.1	2,5	2,2	4	120	34	0,22
JK42HS40-0406	1,8	40	0,4	30	30	2,6	6	150	54	0,28
JK42HS40-1704	1,8	40	1,7	1,5	2.3	4.2	4	150	54	0,28
JK42HS40-1206	1,8	40	1,2	3	2,7	2,9	6	150	54	0,28
JK42HS48-1684	1,8	48	1,68	1,65	2,8	4.4	4	260	68	0,35
JK42HS48-1206	1,8	48	1,2	3,3	2,8	3,17	6	260	68	0,35
JK42HS60-0406	1,8	60	0,4	30	39	6,5	6	280	102	0,5
JK42HS60-1704	1,8	60	1,7	3	6.2	7.3	4	280	102	0,5
JK42HS60-1206	1,8	60	1,2	6	7	5,6	6	280	102	0,5

Figure 2.27 JK42HS28-0504 motors

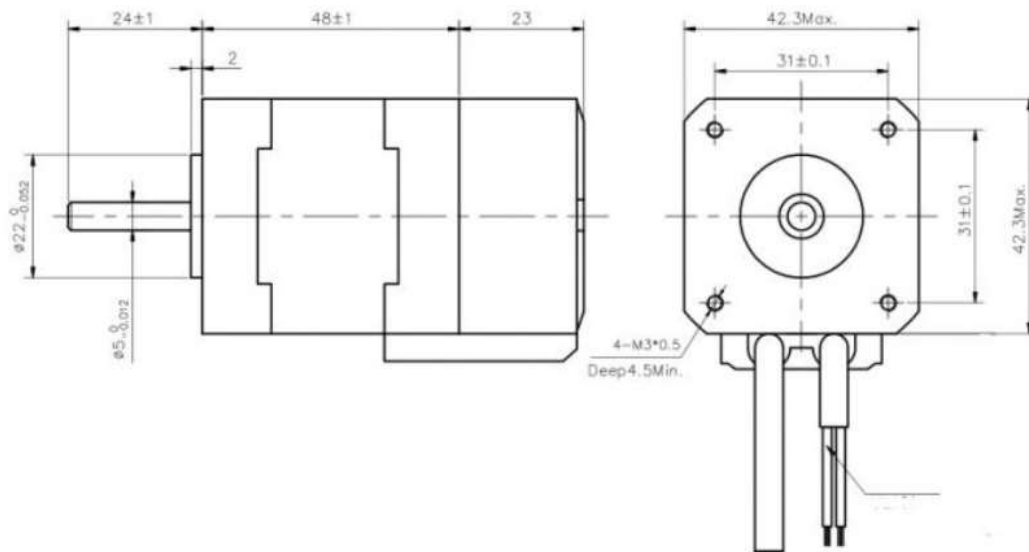


Figure 2.28 JK42HS28-0504 motor

2.4 Model design

With the solutions given for the main problems above, the team will design the 3D model of the machine on Creo design software. And the machine's operating principle will include the following steps:

- Step 1: The tape is placed in the tape box and placed in position.
- Step 2: The robot axis moves with the suction mechanism to take the tape from the box and dip it in methanol and bring it to the position where it needs to be glued. At the same time, the mold and Jig will be positioned by the positioning mechanism.
- Step 3: The robot shaft clamps the tape suction mechanism, then the tape pressing mechanism will light up the tape that needs to be pasted.
- Step 4: The Jig positioning motor will rotate to create the tape pasting motion.
- Step 5: The mold and Jig positioning mechanism will retract to complete the product.

With the above problem solving solutions, the group has designed 3D model options for the corresponding structures.

2.4.1 Tape box model design.

With the above design solution, the tape box design team corresponding to the solution will have a complete structural model as follows:

- Design 1:

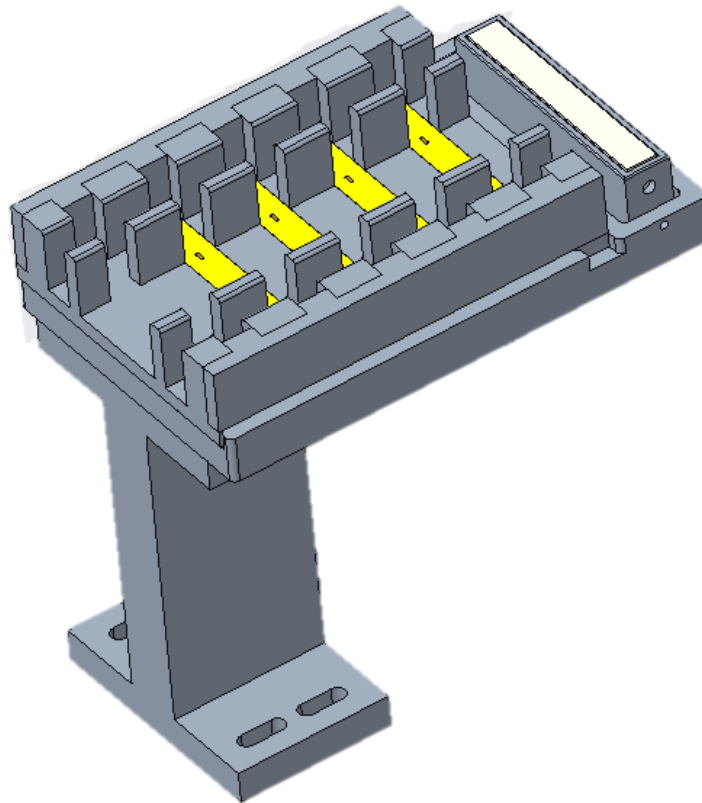


Figure 2.29 3D model of tape box design 1

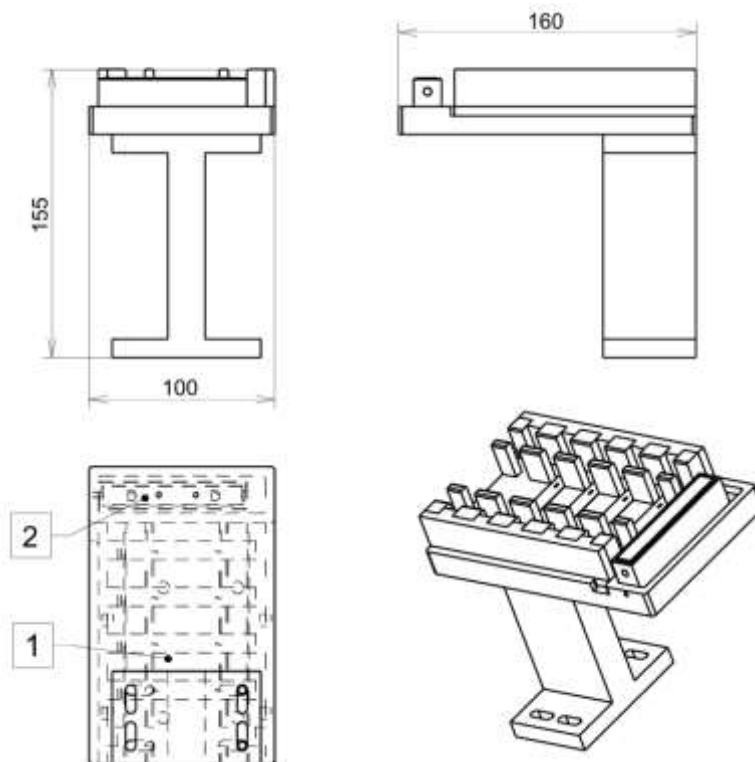


Figure 2.30 Technical specifications of tape box design 1.

- [1] Tape box
- [2] Methanol container
- Design 2:

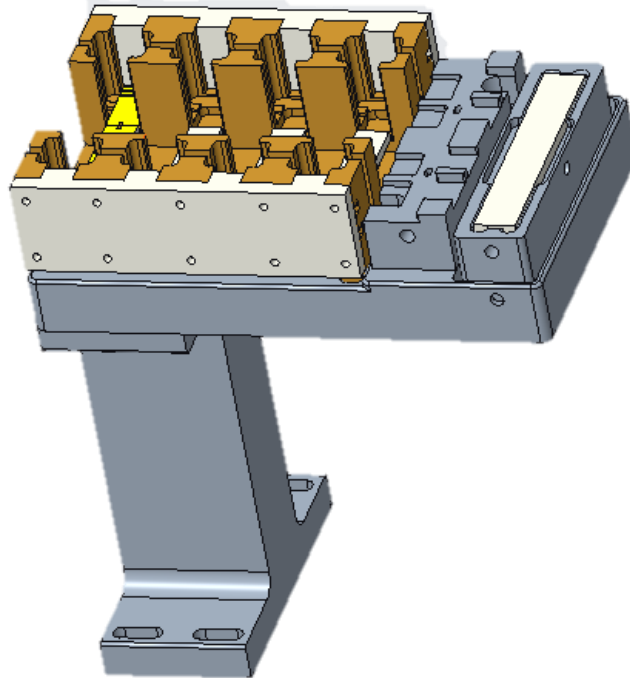


Figure 2.31 3D model of tape box design 2

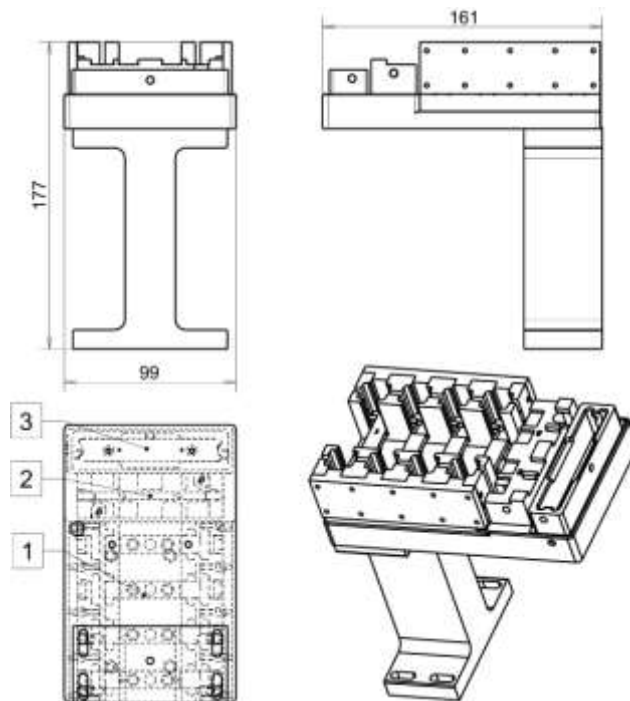


Figure 2.32 Technical specifications of tape box design 2.

- [1] Tape box
- [2] Details of tape flattening by air suction
- [3] Methanol container

2.4. 2 Tape suction mechanism design .

With the above design solution, the tape suction mechanism design team will have the following complete mechanism model:

- Design 1:

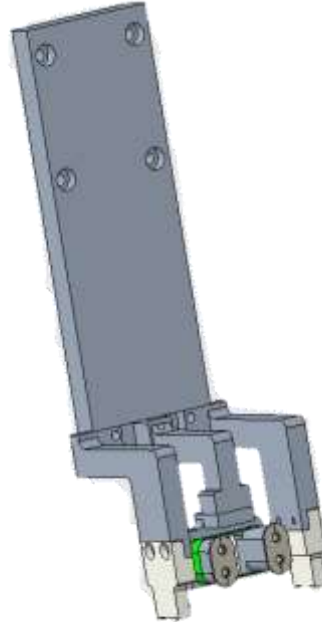


Figure 2.33 3D model of tape suction mechanism design 1.

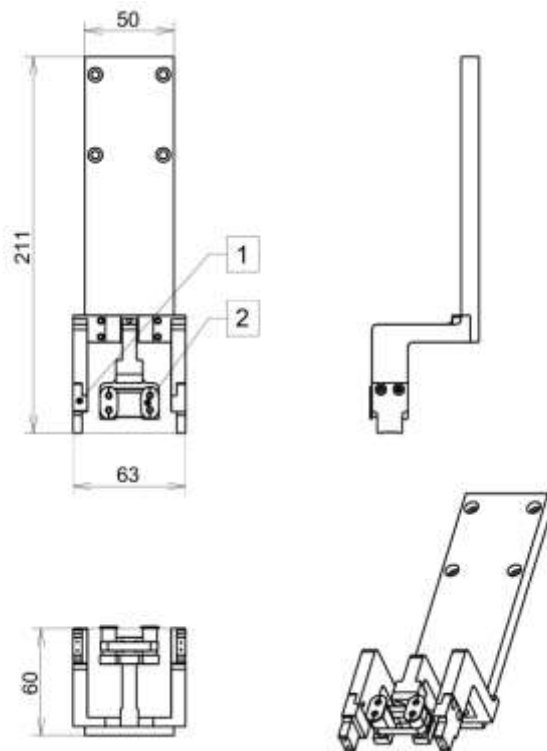


Figure 2.34 Technical parameters of tape suction mechanism design 1.

- [1] tape suction head
- [2] Tape fixing mechanism

- Design 2:

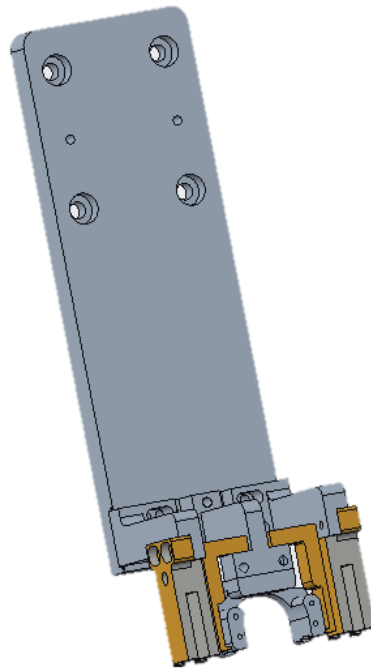


Figure 2.35 3D model of tape suction mechanism design 2.

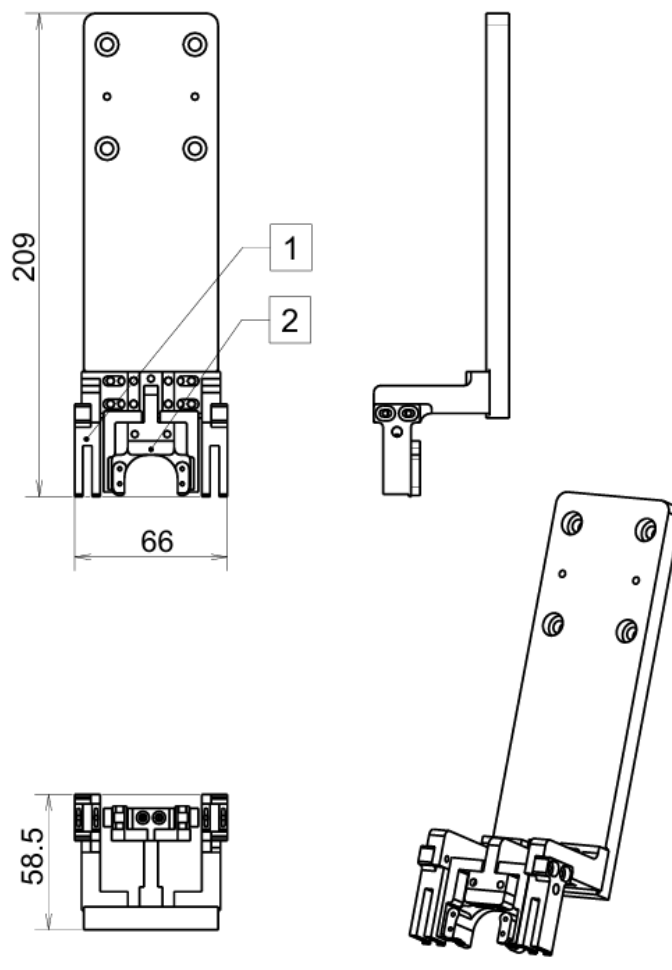


Figure 2.36 Technical parameters of tape suction mechanism design 2.

- [1] tape suction head
- [2] Tape fixing mechanism

2.4.3 Tape paste design .

With the above design solution, the tape gluing mechanism design team will have the following completed mechanism model:

- Design 1:

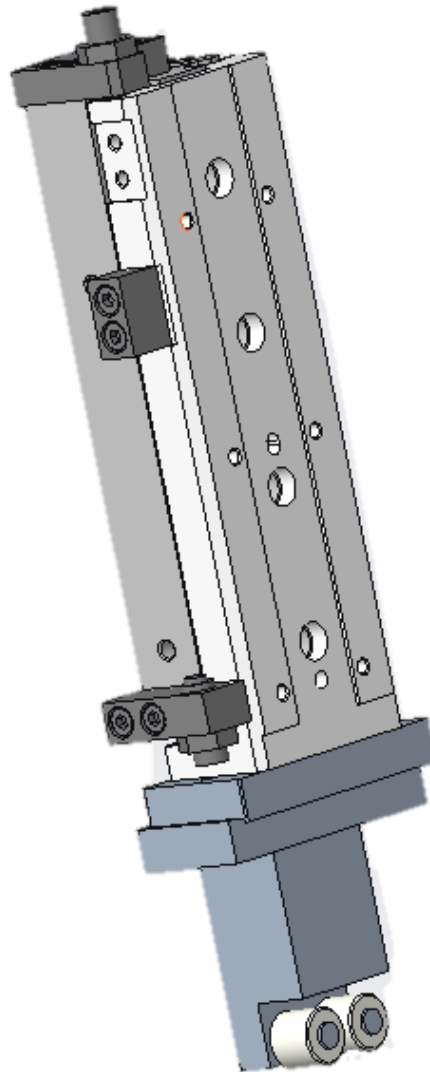


Figure 2.37 3D model of tape pressing mechanism designed 1.

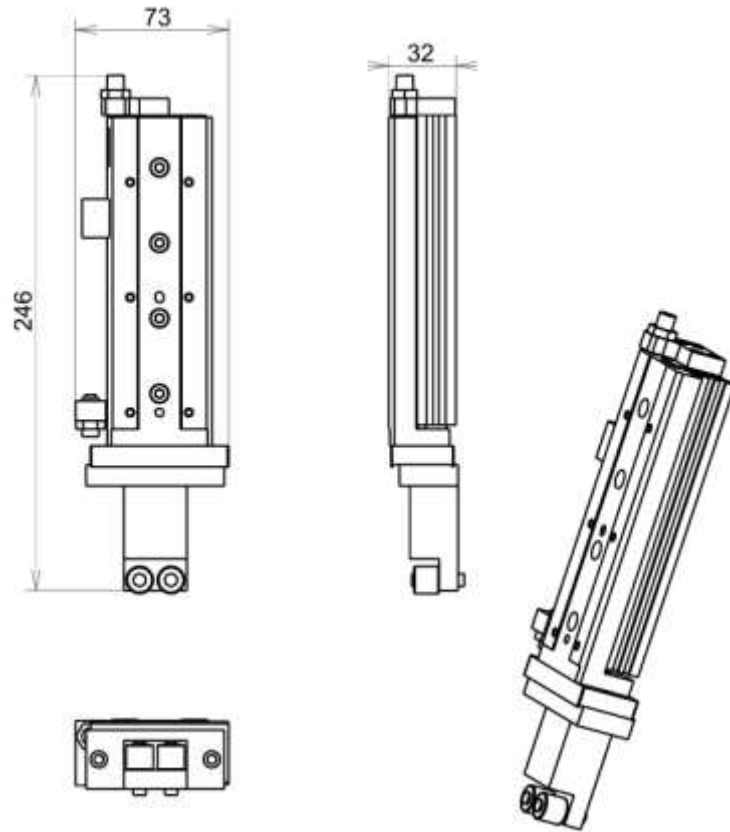


Figure 2.38 Technical parameters of tape pressing mechanism design 1.

- Design 2:

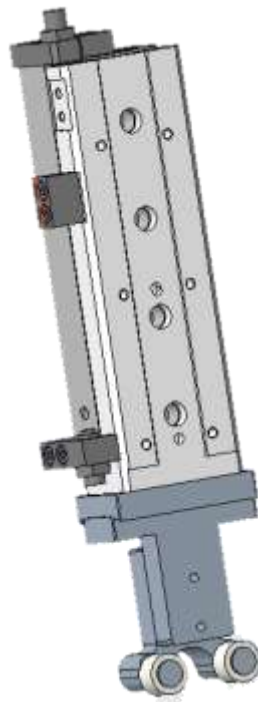


Figure 2.39 3D model of tape pressing mechanism design 2.

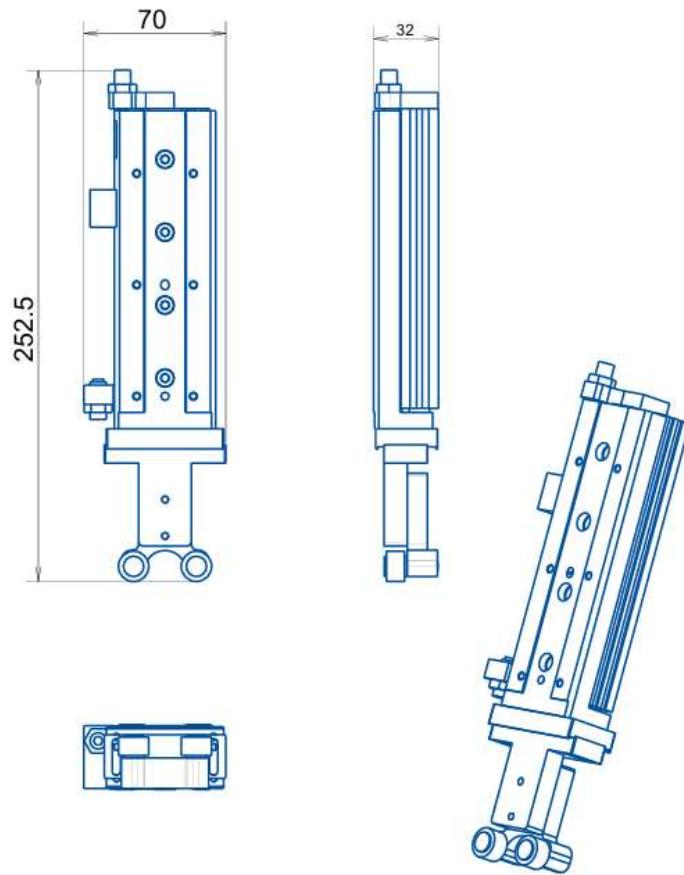


Figure 2.40 Technical specifications of tape pressing mechanism design 2.

- Design 3:

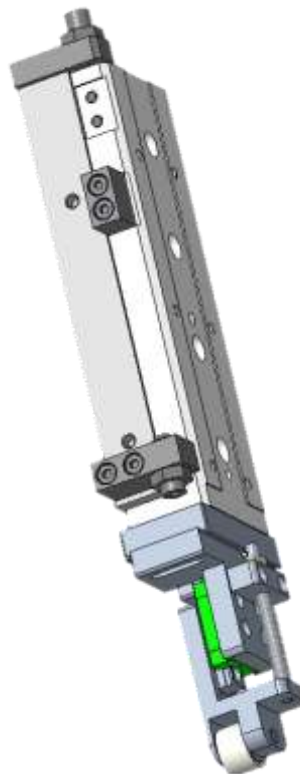


Figure 2.41 3D model of tape pressing mechanism design 3.

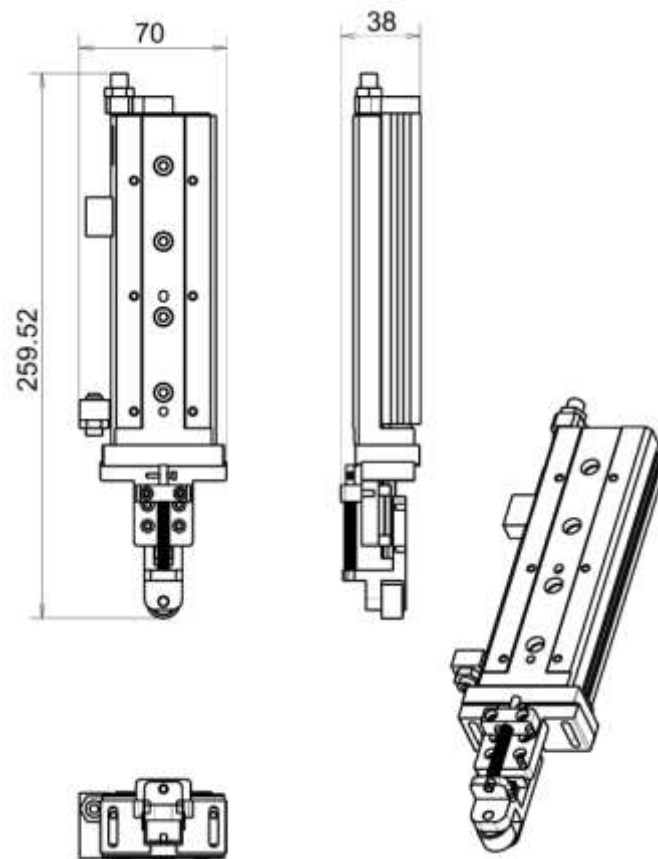


Figure 2.42 Technical parameters of tape pressing mechanism design 3.

2.4. 4 Design of jig and mold positioning .

From the product shape and conveyor, the team designed a Jig positioning mechanism that simultaneously creates a rolling motion to press the tape, and a mold to move through the machines to perform the steps to complete the product.

- Jig Positioning Design.

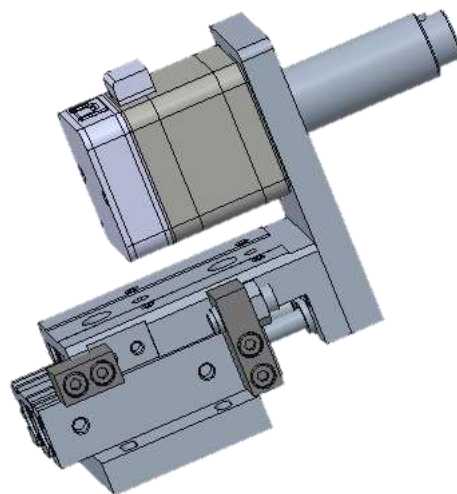


Figure 2.43 3D model of Jig positioning mechanism.

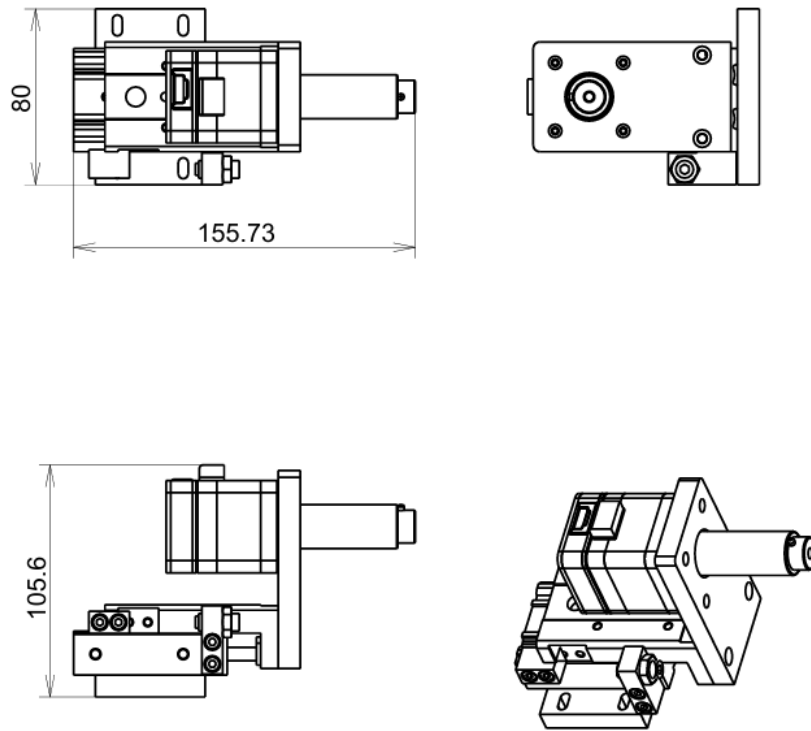


Figure 2.44 Technical parameters of Jig positioning mechanism.

- Mold design.

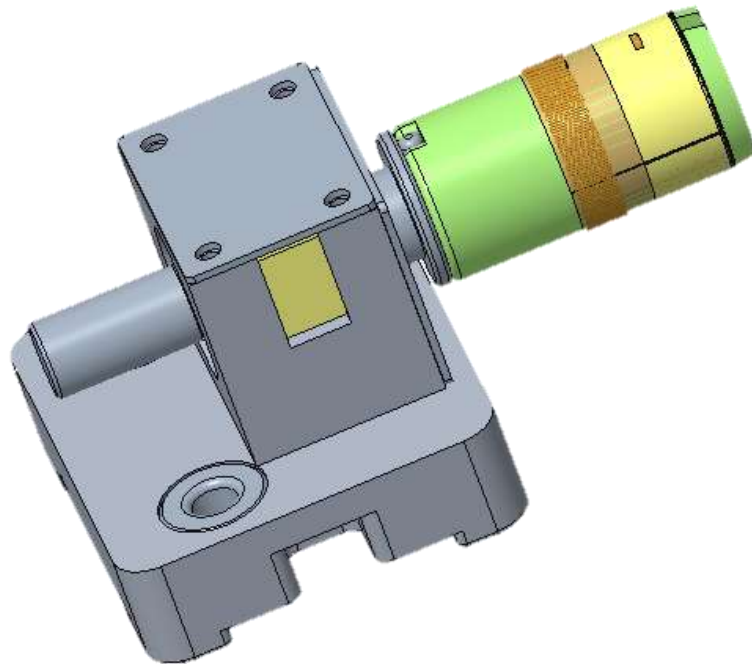


Figure 2.45 3D model of the mold.

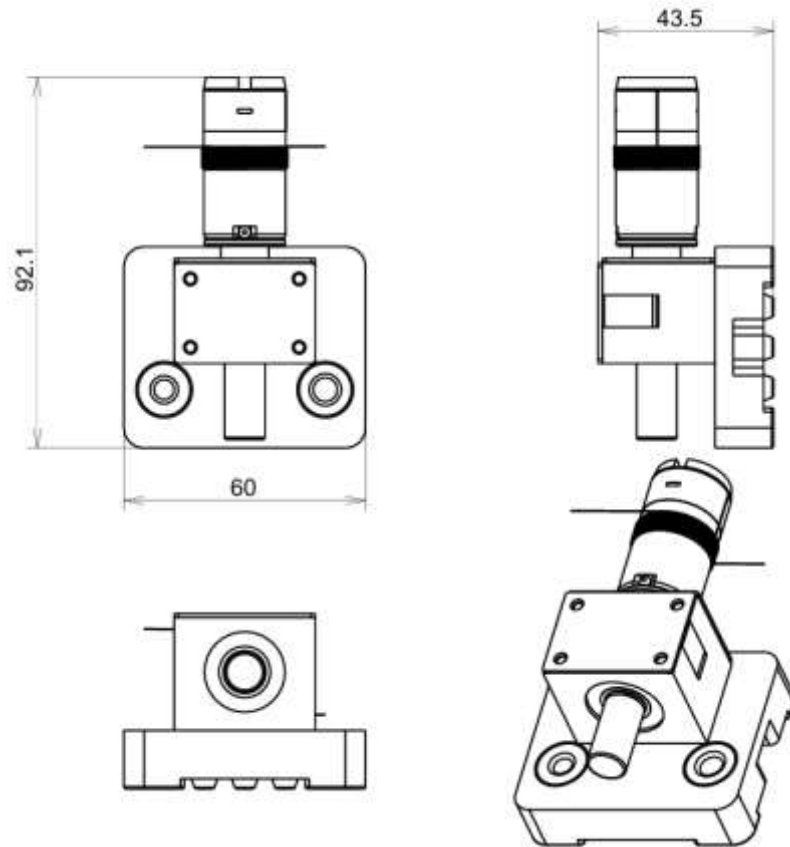


Figure 2.46 Mold specifications.

2.4. 5 Overall machine model design .

From the designed structures, the group will have the following machine design options:

- Design 1

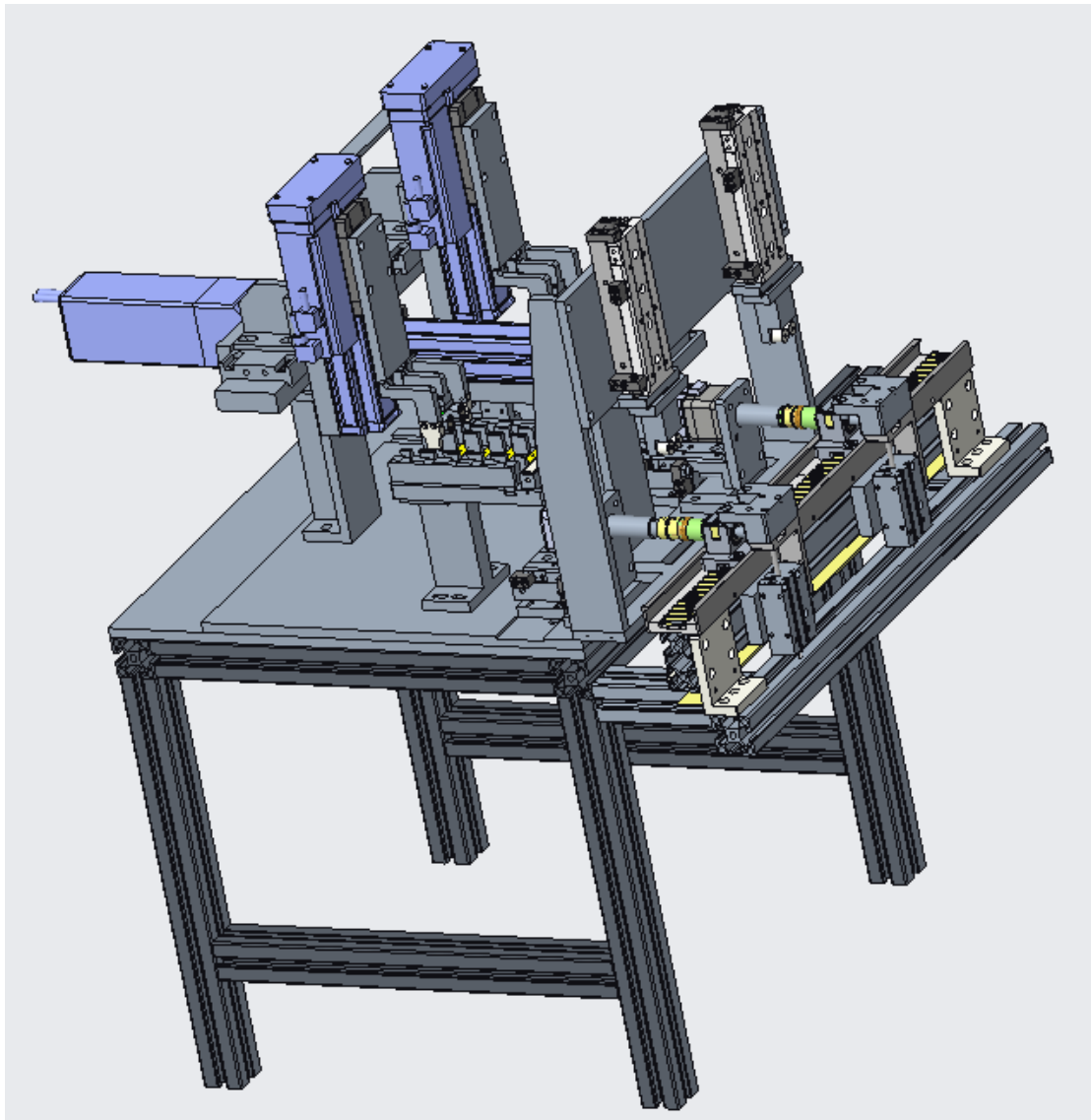


Figure 2.47 Overall 3D model of designed machine 1.

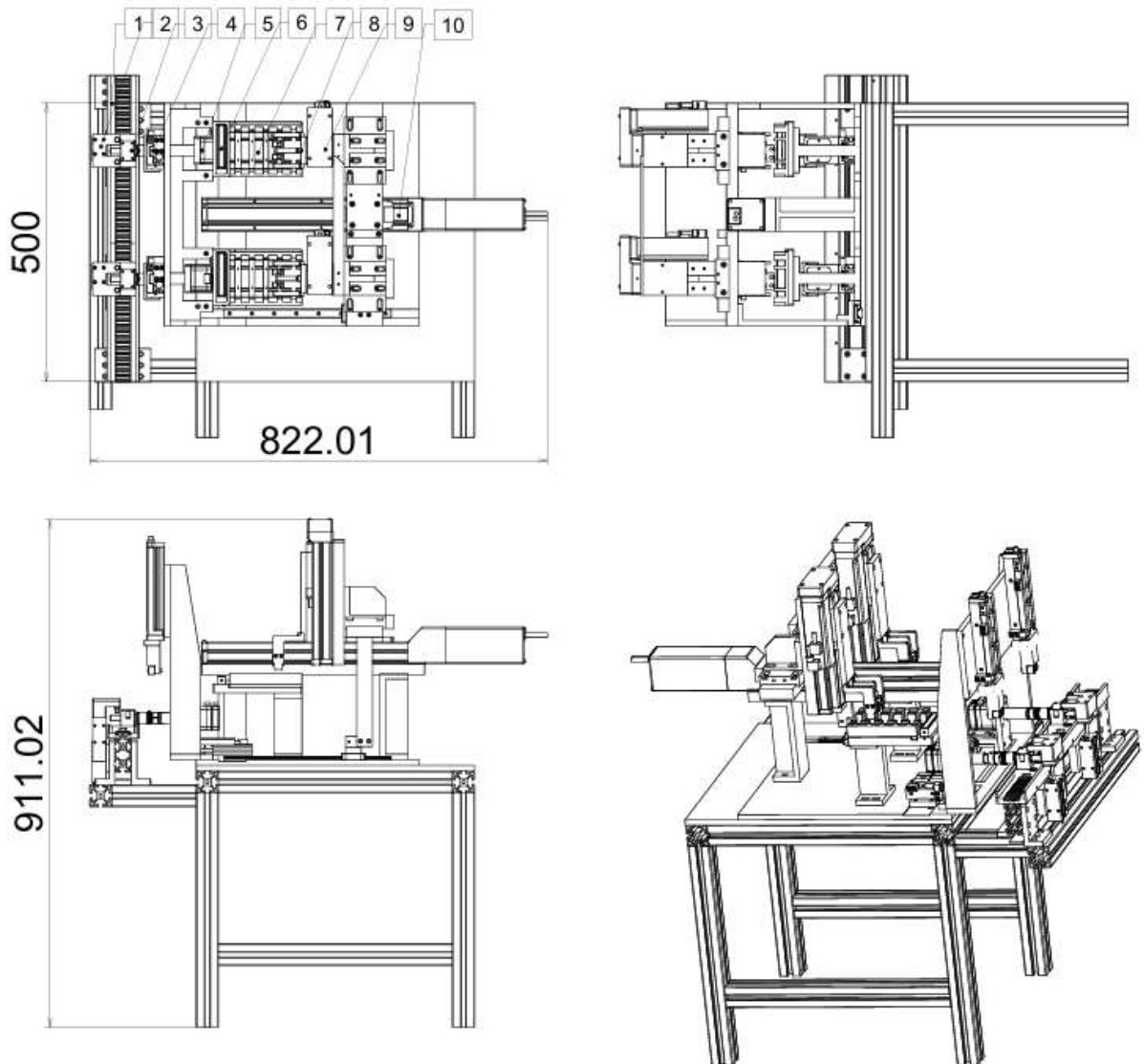


Figure 2.48 Overall technical specifications of the designed machine 1.

The mechanisms are arranged on the machine.

- [1] Converyor belt
- [2] Mold positioning
- [3] Molding
- [4] Tape lamp cluster
- [5] Jig location cluster
- [6] Metanol box
- [7] Tape box
- [8] Bape suction cluster
- [9] Z-axis robot
- [10] y-axis robot

- Design 2:

In the 2-size design, the machine remains the same, only replacing the mechanisms in different design options to improve the machine's accuracy.

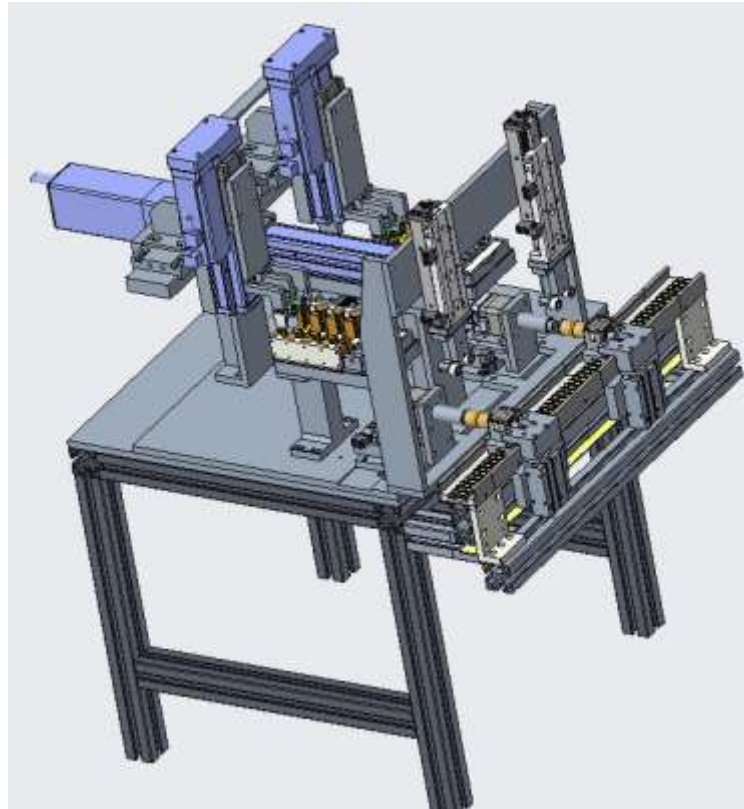


Figure 2.49 Overall 3D model of designed machine 2.

- Design 3:

In the design of 3 sizes of the machine, it is still kept the same, only replacing the mechanisms in different design options to improve the accuracy of the machine and can be used for many different sized products.

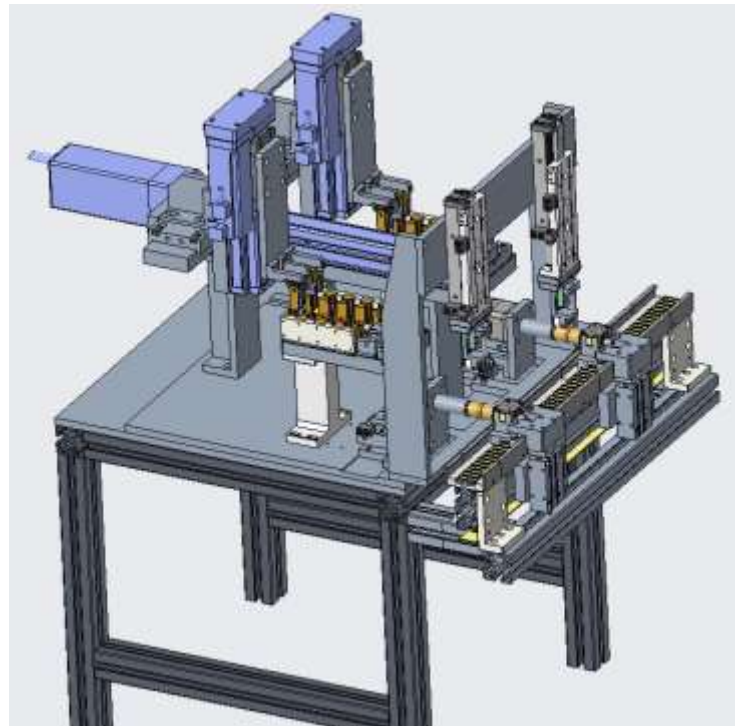


Figure 2.50 Overall 3D model of designed machine 2.

Chapter 3: Control Design

3.1 Block diagram of the system

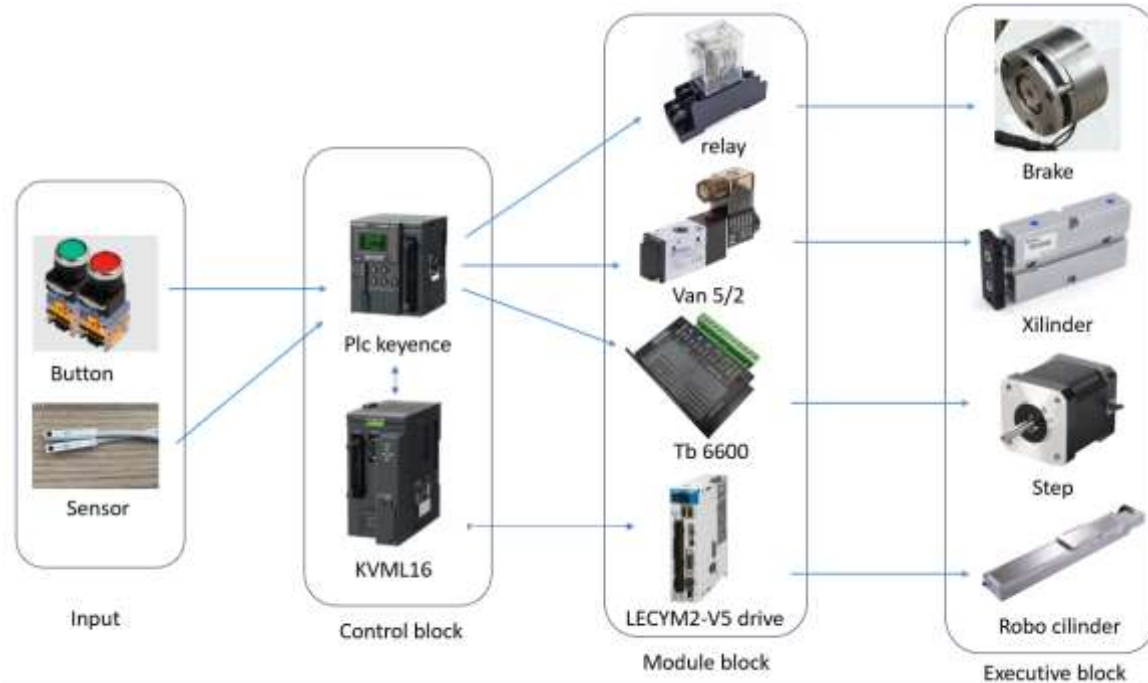


Figure 3.1 System block diagram

Control system diagram using Keyence PLC as control center, coordinating with input devices, communication modules, and actuators to control many devices such as cylinders, stepper motors, linear robots

- Input Block

This is where signals from the operator or environment are received:

- Push button : Used to start or stop the system manually.
- Sensor : Detects the position and status of actuators (for example, detecting that the cylinder has returned to its original position).

These signals are fed into the Keyence PLC for processing.

Control Block:

- Keyence PLC : Is the central controller, receives input signals, processes logic, and controls output to devices in the system.
- Mechatrolink : Is a high-speed communication protocol, used to transmit data between PLC and driver (LECYM2-V5) synchronously, accurately, minimizing noise and connecting wires.

PLC processes signals and controls the operation of devices according to the program programmed in the software.

Module Block:

As a control intermediary between PLC and actuators:

- Relay: An electrical switching device that allows the PLC to control large electrical loads such as brakes .
- 5/2 Valve: Solenoid valve for pneumatic directional control for pneumatic cylinders, with 5 ports and 2 positions.
- Tb 6600: Driver controls step motor, receives signal from PLC to rotate motor in exact number of steps.
- LECYM2-V5 drive: Driver of Robo Cylinder (SMC electric linear axis), receives position control signal from PLC via Mechatrolink.

Actuator Block:

Is where mechanical tasks are performed:

- Brake: Locks movement or holds mechanism position when not in use.
- Cylinder: Pneumatic reciprocating mechanism, controlled via 5/2 valve.
- Step motor: Controls precise movements step by step.
- Robo Cylinder: SMC's high precision electric linear actuator, alternative to air cylinder, easy to program position, speed and thrust.

3.2 PLC controller

3.2.1 General introduction to PLC

PLC (Programmable Logic Controller) is a programmable control device that allows flexible implementation of logic control algorithms through a programming language. PLC operates by scanning the states on the output and input. PLC is used to replace relay circuits in practice because relays have some major disadvantages such as poor quality and worn contacts, difficulty in wiring large numbers of relays, difficulty in modifying wires when the control content changes, and complex and difficult control. Thanks to the following outstanding advantages, PLC has gradually replaced relay control systems in production processes:

- Change the control program flexibly
- Highly reliable
- Small equipment installation space, does not take up much space
- Capable of outputting appropriate electrical signals: current, voltage.
- Easy to change configuration (production machinery system) in the future when there is a need to expand production.

3.2.2 PLC keyence kv 8000

The Keyence KV-8000 PLC is a high-performance programmable logic controller (PLC) series designed to meet modern automation needs with fast processing, diverse communication support, and integrated advanced functions.



Figure 3.2 PLC keyence kv 8000

Outstanding technical features:

High Performance: With fast processing speed, KV-8000 ensures timely response to control requirements in complex industrial applications.

Integrated machine operation recording function: This function allows recording of equipment operation data before and after an incident, helping to quickly identify the cause and reduce downtime.

Diverse communication support: KV-8000 supports popular industrial communication protocols such as EtherNet/IP, Modbus TCP and CC-Link, ensuring flexible connectivity with other devices in the system.

Flexible expansion: The system supports expansion up to 3072 I/O points, suitable for many different application scales.

OPC UA Integration: The KV-8000A version has a built-in OPC UA server, allowing connection to higher-level systems without the need for an intermediate computer, while ensuring data security with advanced security features.

Typical applications:

KV-8000 is suitable for applications requiring high accuracy and reliability such as:

- Automated assembly lines in the electronics and automotive industries
- Industrial robot systems and multi-axis motion control
- Process monitoring and control in the food and pharmaceutical industry
- Energy management and equipment monitoring system in smart factory

3.3 KVML16 robot axis controller



Figure 3.3 KVML16 communication module

Keyence's KV-ML16V module is a 16-axis positioning motion controller, compatible with the MECHATROLINK-II protocol, designed to integrate with KV series PLCs such as KV-8000, KV-7500, KV-7300, KV-5500, KV-5000 and KV-3000.

Main features of KV-ML16V:

- Number of control axes: Supports up to 16 axes, including virtual axes, allowing simultaneous control of multiple actuators in the automation system.
- Communication protocol: Using MECHATROLINK-II, a high-speed communication protocol, helps to minimize interference and ensure accurate data transmission between PLC and peripheral devices such as servo drive or stepper drive.
- Control mode:
 - Position control: Precise positioning of drive shafts.
 - Torque control: Controls the motor's output torque.
 - Speed control: Adjusts the rotation speed of the motor.
 - ML-II command: Communication and control via MECHATROLINK-II command.
 - I/O Control: Manages digital input and output signals.
- Control cycle: Control time varies depending on the number of axes in use:
 - 0.5 ms (maximum 2 axes)
 - 1.0 ms (up to 4 axes)

- 1.5 ms (up to 6 axes)
- 2.0 ms (up to 8 axes)
- 2.5 ms (up to 12 axes)
- 3.0 ms (up to 16 axes)
- Built-in memory:
 - Built-in ROM: 512 KB capacity, allows storage of up to 100 settings.
 - SD Memory Card: Using an SD memory card (KV-MX1 required), up to 1000 settings can be stored, each with a maximum capacity of 8 MB.
- External interface:
 - Input: Use optical input (Photocoupler input).
 - Output: Open collector output with 30 VDC voltage and 50 mA current.

Compatibility:

The KV-ML16V is compatible with the following Keyence PLC series:

- KV-8000
- KV-7500
- KV-7300
- KV-5500
- KV-5000
- KV-3000

Note: KV-ML16V is not compatible with KV-1000 or KV-700 series PLCs.

Additional Specifications:

- Current consumption:
 - Main device: ≤ 200 mA
 - External I/O: ≤ 120 mA
- Weight: About 0.22 kg

Practical application:

The KV-ML16V is ideal for applications requiring precise and synchronized motion control of multiple axes, such as:

- Automatic production line.
- Industrial robot systems.
- CNC machines and mechanical processing equipment.
- Product packaging and sorting system.

3.4 Driver LECYM2-V5



Figure 3.4 LECYM2-V5 Driver

3.4.1 Overview

The LECYM2-V5 is an AC servo motor controller manufactured by SMC, part of the LECYM Series, designed to control electric drive axes such as Robo Cylinder. The device supports the MECHATROLINK-II communication protocol, allowing easy integration with modern PLC systems such as the Keyence KV-3000 via a compatible communication module.

3.4.2 Main technical parameters

- Main power supply : 3 phase voltage from 200 to 230 VAC (50/60 Hz)
- Control power supply : 1 phase voltage from 200 to 230 VAC (50/60 Hz)
- Compatible motor power : 100 W
- Encoder type : 20-bit absolute encoder with resolution of 1,048,576 p/rev
- Communication protocol: MECHATROLINK-II, supports maximum transmission speed of 10 Mbps and connects up to 30 devices with a total maximum cable length of 50 m
- Safety function: Supports STO (Safe Torque Off) function to ensure safety during operation

- Size and weight: About 600 g , compact design suitable for installation in limited spaces

3.4.3 Compatibility and application

LECYM2-V5 is compatible with AC servo motors with a power of 100 W and is widely used in industrial automation applications such as:

- Pick-and-place system: Precise positioning of objects in the production line
- Packaging Machine: Precise motion control of packaging mechanisms
- Assembly line: Synchronize motion between axes to assemble products
- Industrial Robot Systems: Control the motion axes of robots in applications such as welding, painting, or assembly

3.5 Driver Tb6600

3.5.1 Overview



Figure 3.5 Tb6600 Driver

TB6600 is a popular stepper motor driver, designed to control 2-phase stepper motors, especially in CNC, 3D printing, or small-scale industrial robotics applications. It is a low-cost, easy-to-use, and efficient solution for motion control systems.

3.5.2 Main technical parameters

- Main control IC : Toshiba TB6600HG
- Supported motor type : 2-phase stepper motor , 4-wire or 6-wire (parallel or series connection)
- Input voltage : 9V to 42V DC

- Output load current : Maximum 4.0A (peak) , adjustable to the following levels:
 - 0.5A, 1A, 1.5A, 2A, 2.5A, 3A, 3.5A, 4A
- Microstepping : Supports microstepping resolution with levels:
 - Full, 1/2, 1/4, 1/8, 1/16, 1/32
- Control signal :
 - PUL+ / PUL- (pulse): Create steps for the motor
 - DIR+ / DIR- (rotation direction): Decides the rotation direction
 - ENA+ / ENA- (enable): Enable or disable control

3.5.3 Connection

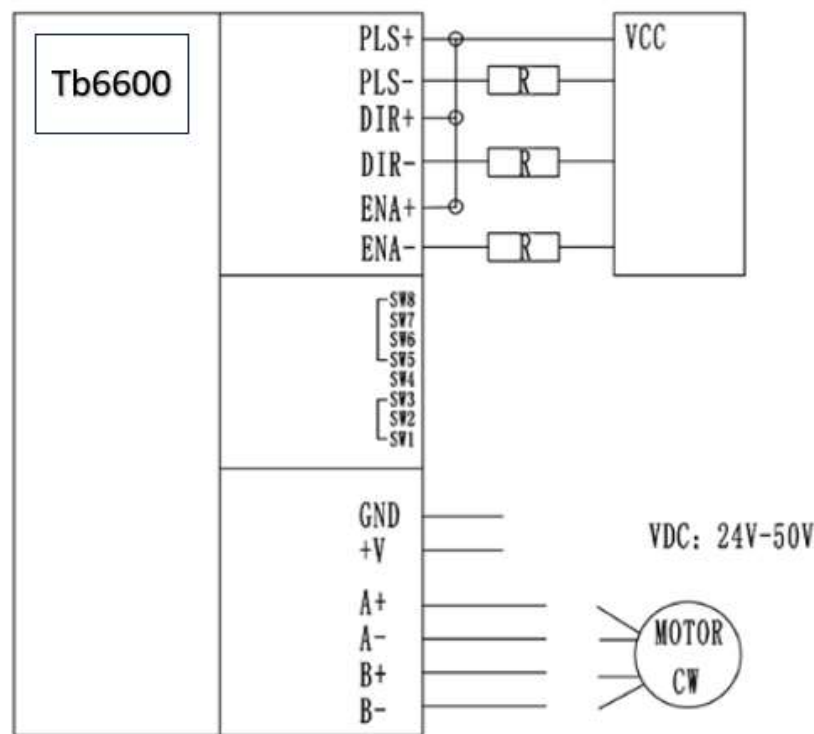


Figure 3.6 Tb6600 wiring diagram

Control input: TTL logic 5V/3.3V (compatible with Arduino, STM32, PLC like Keyence)

Motor output: Direct connection to 2 phases A/A- and B/B-

Separate power supply: Requires separate power supply for motor (do not share power with controller)

Advantage

- Low cost
- Easy to install and set up
- Compatible with a wide range of microcontrollers and PLCs
- Support large current and high microstepping

- Built-in over current, over temperature, short circuit protection

3.6 Relay



Figure 3.7 Relay

A relay is an electrically operated switch. The current flowing through the relay coil creates a magnetic field that attracts the soft iron core, which changes the switch. The current through the coil can be turned on or off, so the relay has two switching positions. Relays are commonly used in automatic control circuits, specifically for switching large currents that control circuit systems cannot directly intervene. On the relay there are 3 symbols: NO, NC and COM

- COM (Common): is the common pin where the standby power supply line is connected, it is always connected to 1 of the 2 remaining pins. Which pin it is connected to depends on the operating status of the relay.
- NC (Normally Closed): When the relay is in the OFF state, the COM pin will be connected to this pin.
- NO (Normally Open): When the relay is in the ON state (current flows through the coil), the COM pin will be connected to this pin.

3.7 5/2 valve

The 5/2 pneumatic valve is a type of pneumatic solenoid valve, also known as a 5/2 reversing valve, used to control the flow of compressed air into pneumatic devices such as cylinders or valve controllers using compressed air with a 5-port, 2-position design. The pneumatic solenoid valve or actuator is powered by supplying 220VAC or 24VDC power to the coil head. At this time, the magnetic force will be generated to attract the valve shaft to move along the axis, opening the valve doors to allow compressed air to pass through the door and perform the task of supplying or closing the compressed air flow to the device that needs to operate. The function of the 5/2 pneumatic solenoid valve is to control the operating status of the double-acting

pneumatic cylinder through the opening and closing of the compressed air supply and discharge ports .



Figure 3.8 5/2 solenoid valve (Source: Internet)

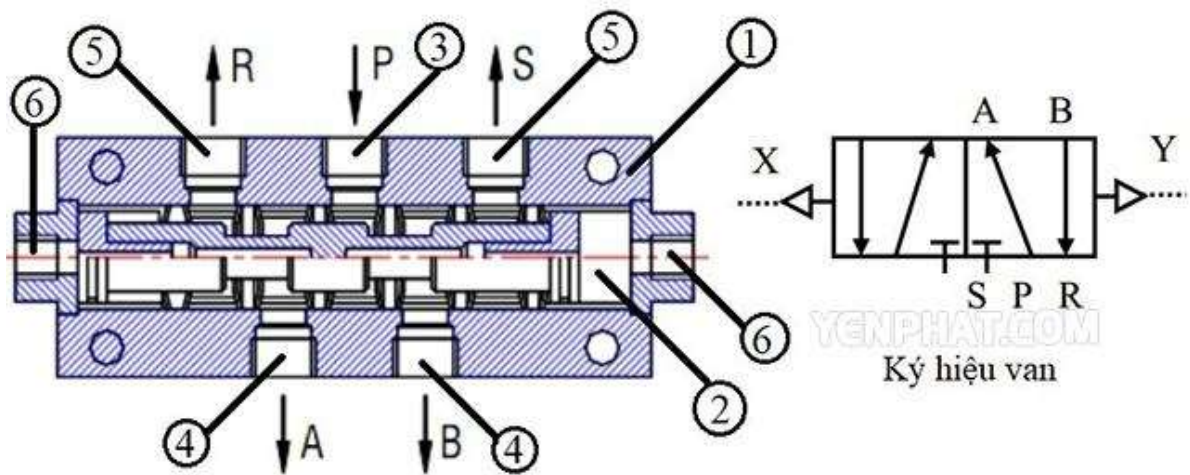


Figure 3.9 Structure of 5/2 valve (Source: Internet)

3.8 Wiring diagram

3.8.1 IN-OUT ports

TERMINAL KV-C32-XTD (INPUT_ OUTPUT)			
Symbol	Input	Symbol	Output
SS_XL kep khuôn 1_1	1	Xi_Lanh kep khuôn 1	1
SS_XL kep khuôn 1_2	2	Xi_Lanh kep khuôn 2	2
SS_XL kep khuôn 2_1	3	Xi_Lanh tape 1	3
SS_XL kep khuôn 2_2	4	Xi_Lanh tape2	4
SS_XL Tape 1_1	5	Đèn	5
SS_XL Tape 1_2	6	Còi	6
SS_XL Tape 2_1	7	Xi_Lanh cap nuoc	7
SS_XL Tape 2_2	8		
SS_XL hut 1_1	9		
SS_XL hut 1_2	10		
SS_XL hut 2_1	11		
SS_XL hut 2_2	12		
Start	13		
Stop	14		
SS_cap nuoc 1	15		
SS_cap nuoc 2	16		

Figure 3.10 IN-OUT pin diagram

3.8.2 Wiring diagram

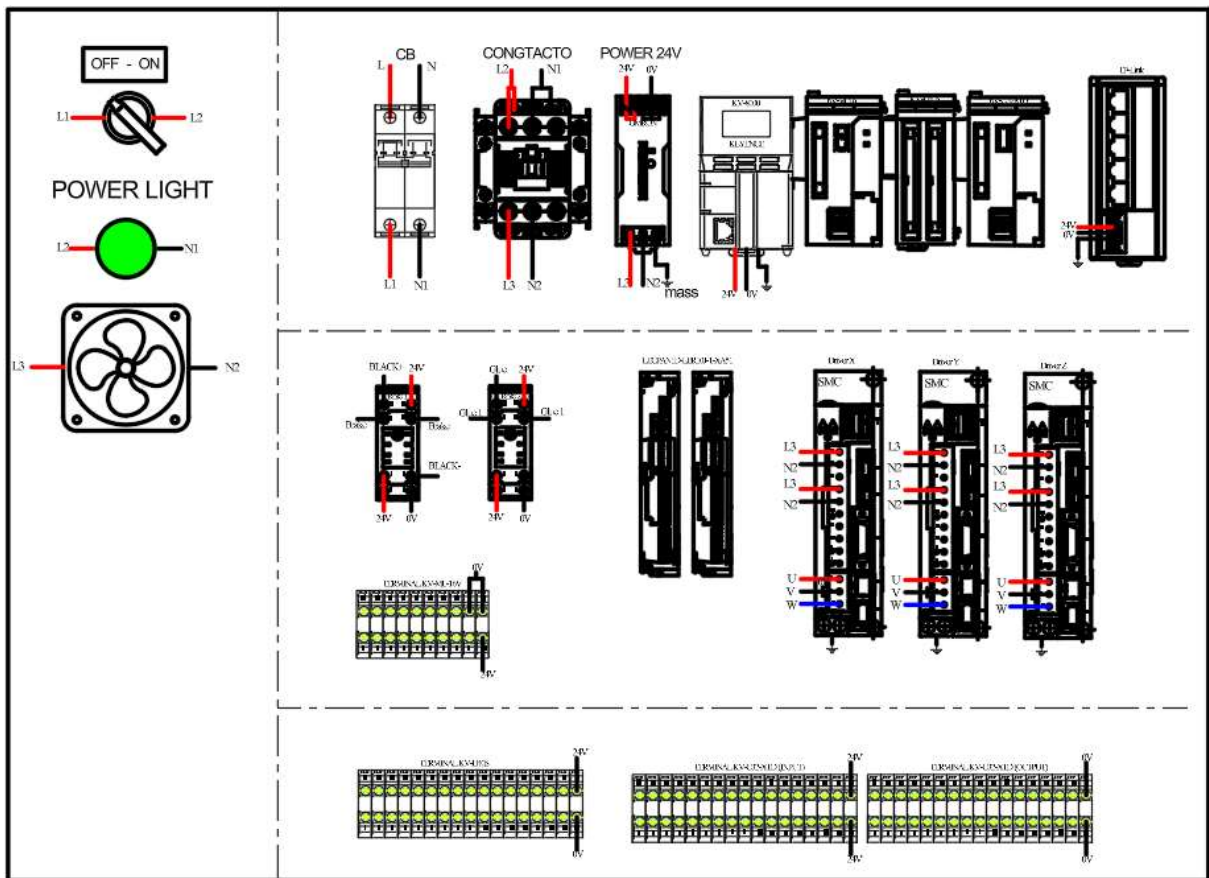


Figure 3.11 Component layout

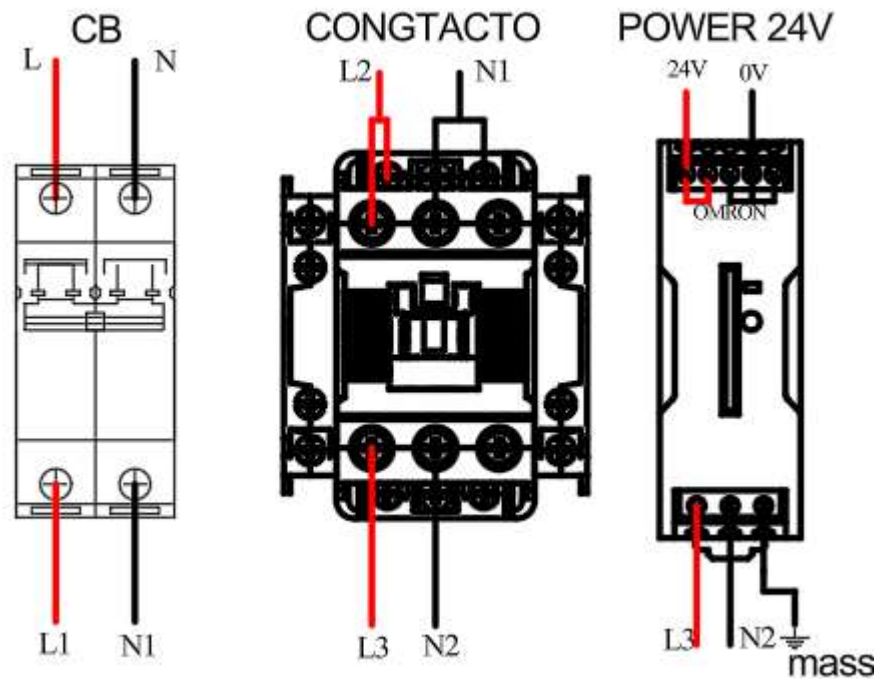


Figure 3.12 power supply

Power Supply and Protection Devices

- OFF-ON Switch (top left corner): Used to turn the 3-phase main power supply to the panel ON or OFF.
- CB (Circuit Breaker): Protects the circuit from overcurrent.
- Contactor: An electromechanical switch used to control the power to the load.
- POWER INDICATOR LIGHT: Lights up when the panel receives power.
- Cooling Fan: Connected to L3–N2, used to ventilate and cool the electrical panel.

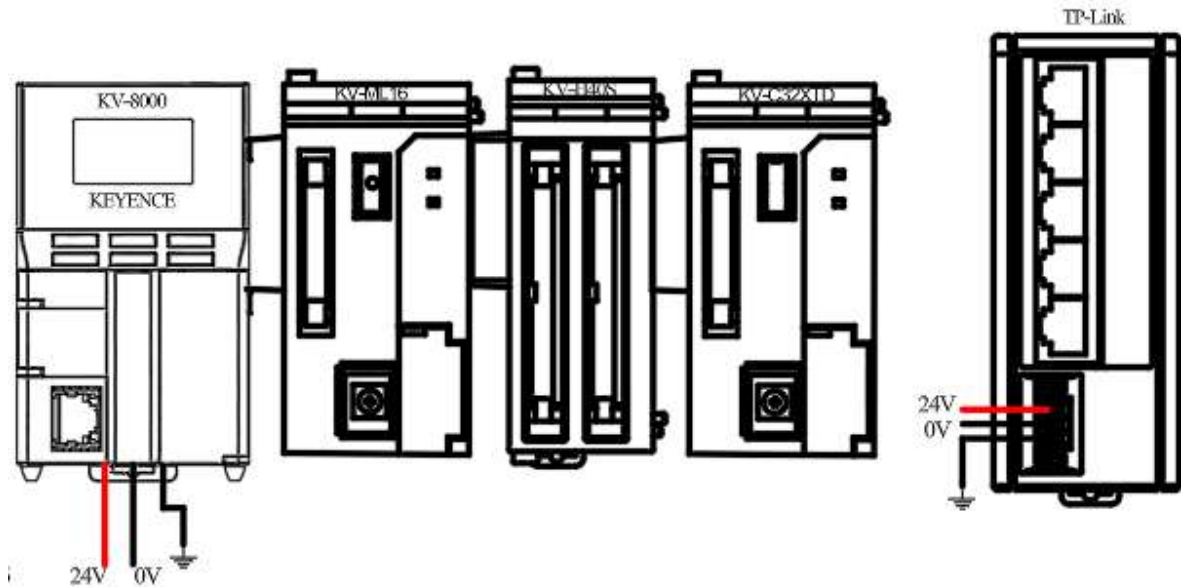


Figure 3.13 Control Block

The KEYENCE KV-8000 PLC is the main control center, responsible for processing signals from sensors, buttons, limit switches, and controlling actuators such as cylinders, motors, conveyors, etc.

Through the TP-Link Switch, the system can communicate via Ethernet, supporting Modbus TCP/IP transmission or proprietary protocols between the PLC and peripheral devices.

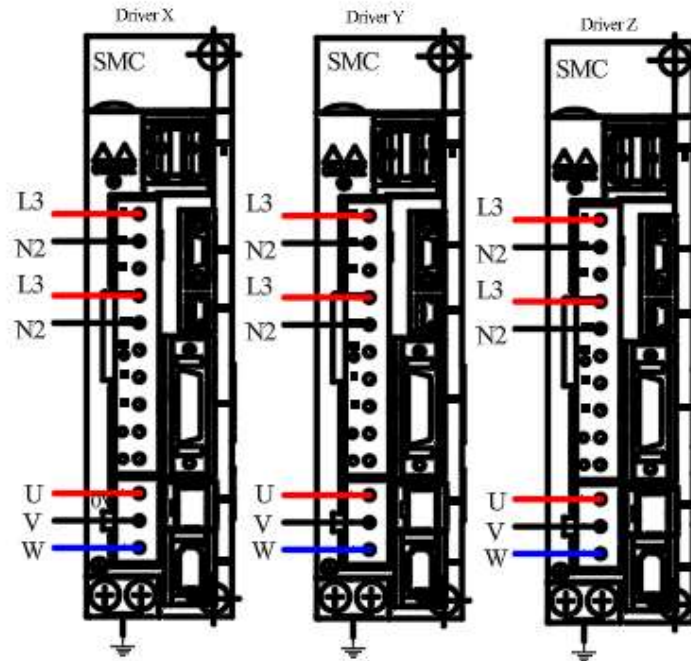


Figure 3.14 Driver Block

Power Supply Input: L3, N2 (red lines): These are the power inputs to the driver, typically 220V or 380V depending on the system design.

The power is usually supplied from the main control panel or through a protected contactor.

Motor Output Terminals: U, V, W (red and blue lines): These are the three-phase outputs from the driver to the corresponding servo motor of each axis.

These outputs generate a rotating magnetic field in the motor stator to control the rotor's movement.

Grounding (Earth): Ground wires ensure electrical safety, noise shielding, and equipment protection in case of leakage current.

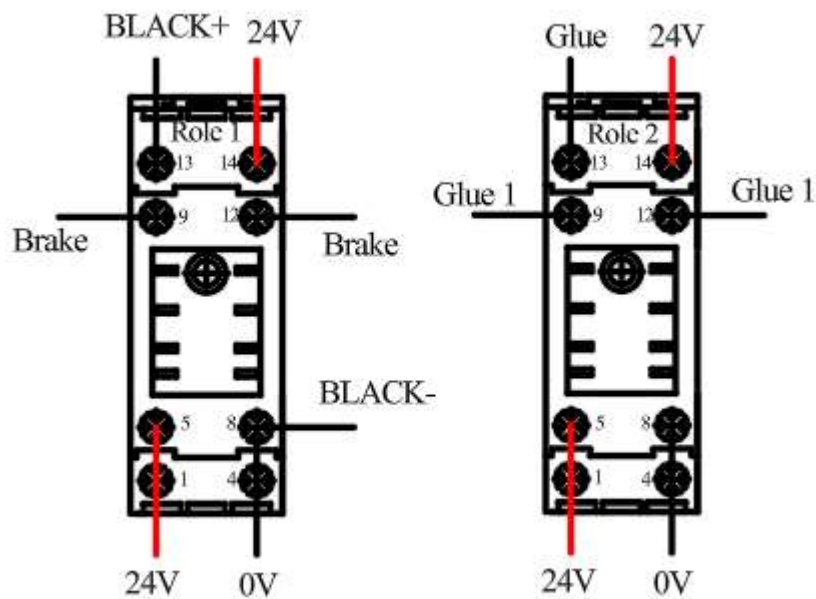


Figure 3.15 Relay Block

This block contains two intermediate relays (Role 1 and Role 2), which act as electronic switches. They allow low-voltage control signals (typically 24V) to control external devices such as brake actuators or glue dispensers.

Left Relay – ROLE 1: Brake Control

- BLACK+ (Pin 14): Connected to 24V DC, supplying voltage to the relay coil.
- BLACK- (Pin 5): Connected to 0V, completing the relay coil circuit.
- When the relay is energized (activated), the switching contacts connect power through terminals 11 and 14 to the Brake output (pins 9 and 13), which triggers the braking mechanism in the system.

Right Relay – ROLE 2: Glue Control

- GLUE (Pin 14): Connected to a 24V control signal to activate the relay.
- GLUE 1 (Pin 5): Connected to 0V.
- When the relay is triggered, the contact closes, allowing current to flow from the 24V supply through the relay to activate the glue dispensing device (via GLUE 1 – pins 9/13 or 8/12 depending on configuration).

3.9 Electrical cabinet design

With the system diagram mentioned above, we arrange the components into the electrical cabinet and design the electrical cabinet.

3.9.1 General description of the electrical cabinet

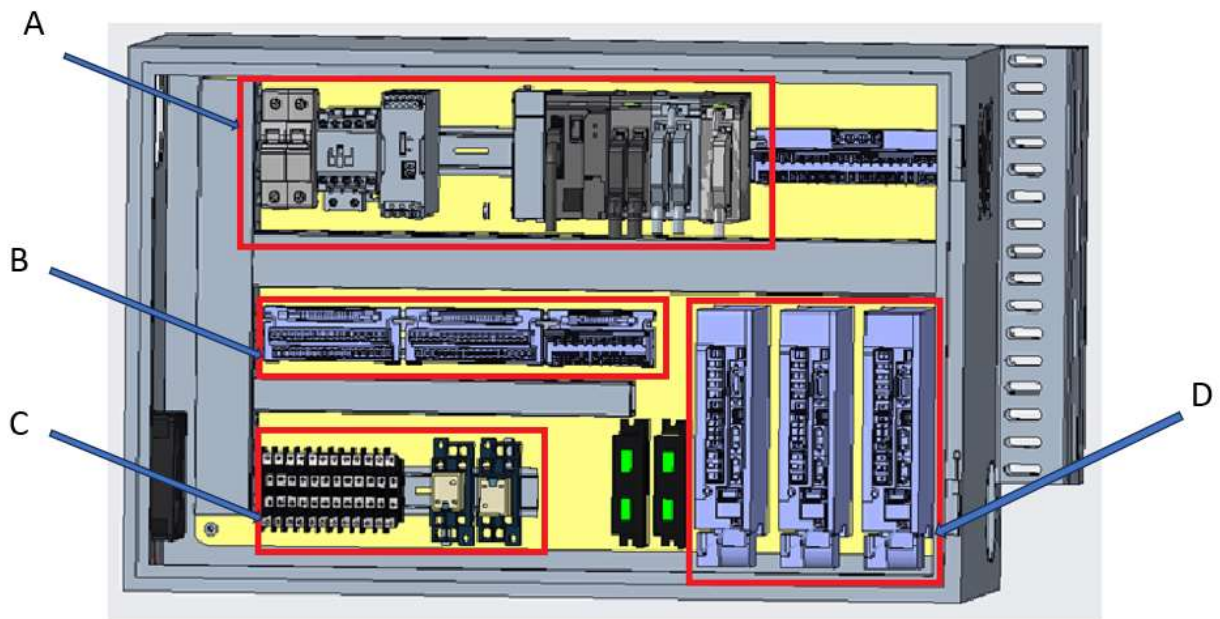


Figure 3.16 3D electrical cabinet of the machine

This electrical cabinet is designed to control an automatic execution system using Keyence PLC, Mechatrolink communication, and motor/robo cylinder control drivers. The components are arranged clearly and neatly by layer and function, ensuring easy connection, easy maintenance, effective power and signal isolation.

3.9.2 Functional zoning in the cabinet

(A) Top – Central Control Unit

- Keyence PLC (center): Is the control center that processes signals from input and outputs commands to the actuators.
- I/O and communication expansion modules (Mechatrolink) : Attached to the PLC to expand connectivity (can be KV-ML16 module or equivalent).
- I/O signal connection terminal bar : On the right edge, used to connect signals from sensors, push buttons, relays, etc.

(B) Middle row – Input/output connection block and control signal

- Horizontal terminal (purple): Used to connect external signal wires such as magnetic sensors, limit switches, push buttons.
- Intermediate relay or signal isolator: Black and green modules can be seen used to amplify or isolate signals before controlling the load or PLC.

(C) Bottom left corner – Power supply and protection block

- CB, circuit breaker, MCB, protection device: Provide and protect 1-phase/3-phase power for other blocks.
- Switching power source (if available): Converts AC power to 24VDC for PLC, sensors, relays.

(D) Lower right corner – Drive actuator block

- Control driver (blue): These are SMC's LECYM2-V5 drivers , controlling Robo Cylinders via the Mechatrolink protocol.
- Drivers are arranged close together, easy to connect power wires and encoder/motor.
- Can be connected in parallel with the communication unit on PLC via Mechatrolink cable.

3.9.3 System operation logic in the cabinet

Signal from sensor, push button → to middle row terminal → goes to PLC for processing.

PLC logic processing: Based on sensor status, push button, operating command.

PLC output control signal:

- To relay (in middle row) to turn on/off brake, 5/2 valve, step motor (TB6600).
- Send position transmission command to LECYM2-V5 driver to control robo cylinder.

The actuators perform the task, and the sensors feedback the new state to the PLC → cycle repeats.

3.10 Algorithm flowchart

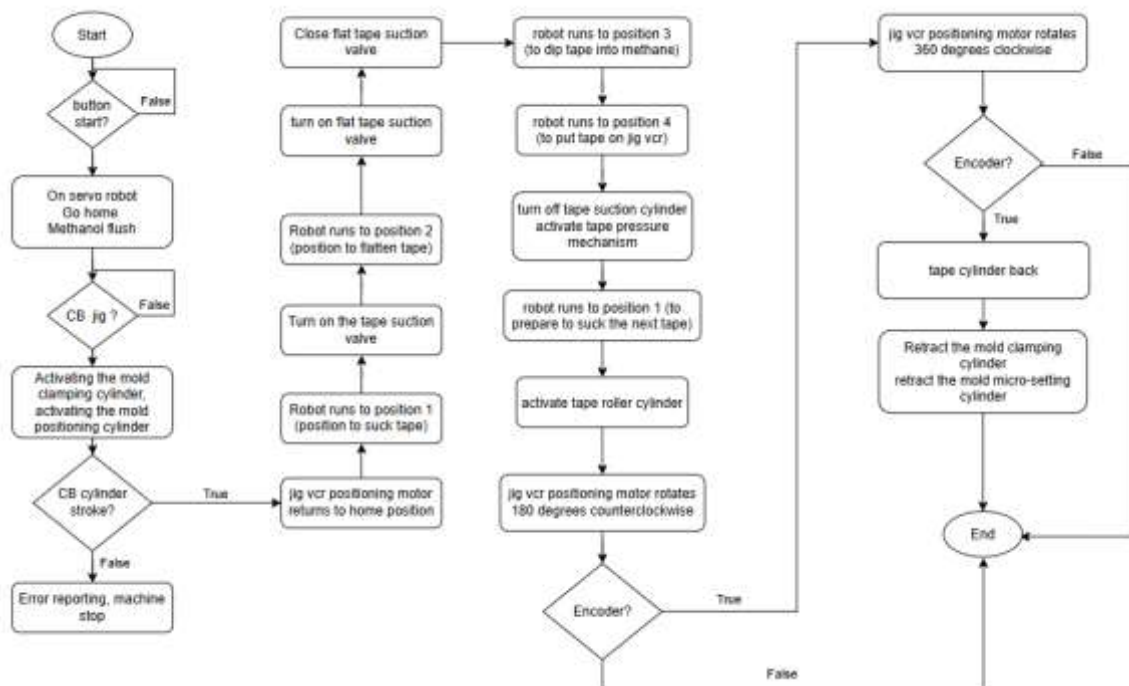


Figure 3.17 Algorithm flowchart of the system

The flowchart describes the automatic control algorithm of a robot tape pick-and-stick machine combining a jig, cylinder and suction valve mechanism, commonly found in automated machines assembling electronic components or precision mechanics.

1. Start

- Start → System waits for Start button to be pressed
- If not pressed: continue waiting

- If pressed:
 - Turn on robot servo
 - Robot returns to home position
 - Drain methanol (prepare work environment)

2. Confirm input conditions

- Check the jig CB (sensor to check if the jig is installed correctly)
 - If false: no jig → wait
 - If true:
 - Activate the mold clamp cylinder
 - Activate the mold positioning cylinder

3. Check cylinder stroke

- If cylinder stroke is successful (stroke CB = true): continue
- If not (false): report error and stop the machine

4. Suction and tape application process

Round 1 :

- Jig motor returns to angle position (reset 0°)
- Robot runs to position 1 → tape pick-up position
- Turn on the tape suction valve
- Robot runs to position 2 → paste flat tape
- Turn on flat suction valve
- Robot goes to position 3 → dips tape into methanol
- Robot to position 4 → stick tape on VCR jig
- Turn off the suction valve, activate the tape pressure mechanism.

Round 2 (prepare next tape):

- Robot returns to position 1
- Activate tape roller cylinder
- Jig rotates 180° counterclockwise
- Repeat the process: take the tape → stick it a second time as above
- Then the jig rotates 360° clockwise.

5. End of cycle

- Tape roller cylinder back
- Retract the mold clamp cylinder
- Retract mold positioning cylinder
- End

3.11 GUI

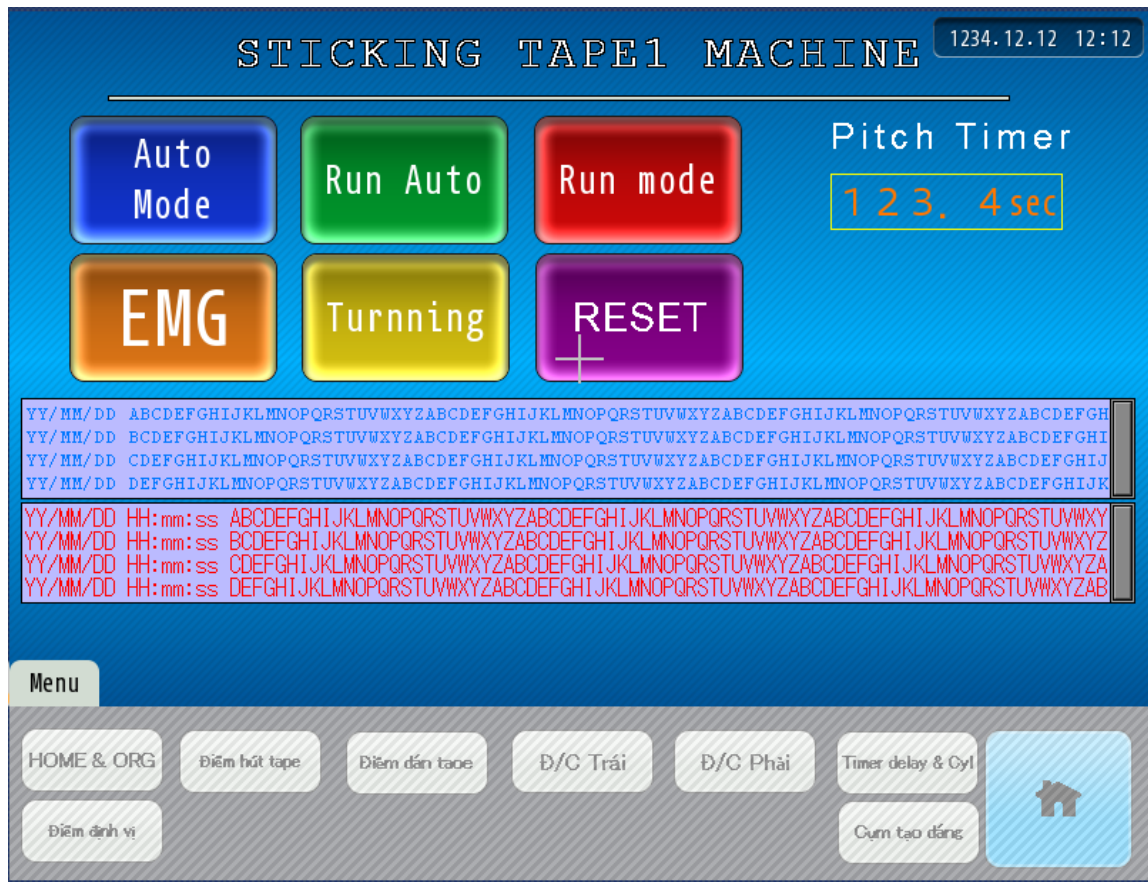


Figure 3.18 Main screen interface

Main screen interface to display and select manual or automatic running mode , display menus to transition to machine parameter setting screen pages. The function of the buttons is explained as follows:

Auto Mode: This button is used to switch between auto mode and manual mode.

EMG: Use in emergencies

Run Auto: when in auto mode, press this button to start running the machine automatically.

The menu area is used to select the robot's coordinates, customize the motor's rotation angle, and customize the machine's delay time.

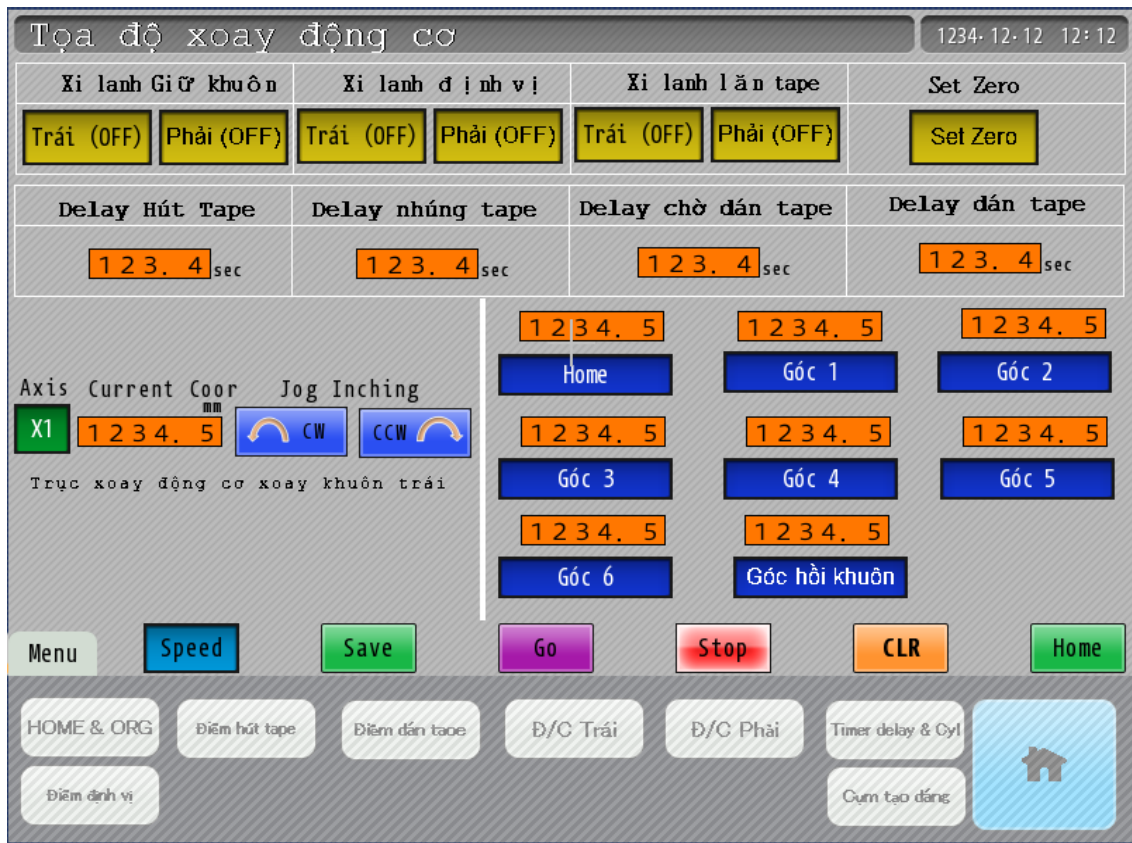


Figure 3.19 Motor rotation angle setting screen

To set the motor rotation angle, first jog the motor to the angle to be set, then select the point to be set, and enter the desired angle value.

Press the 'speed' button to set the speed for the motor according to each rotation angle. Set the remaining motor similarly.

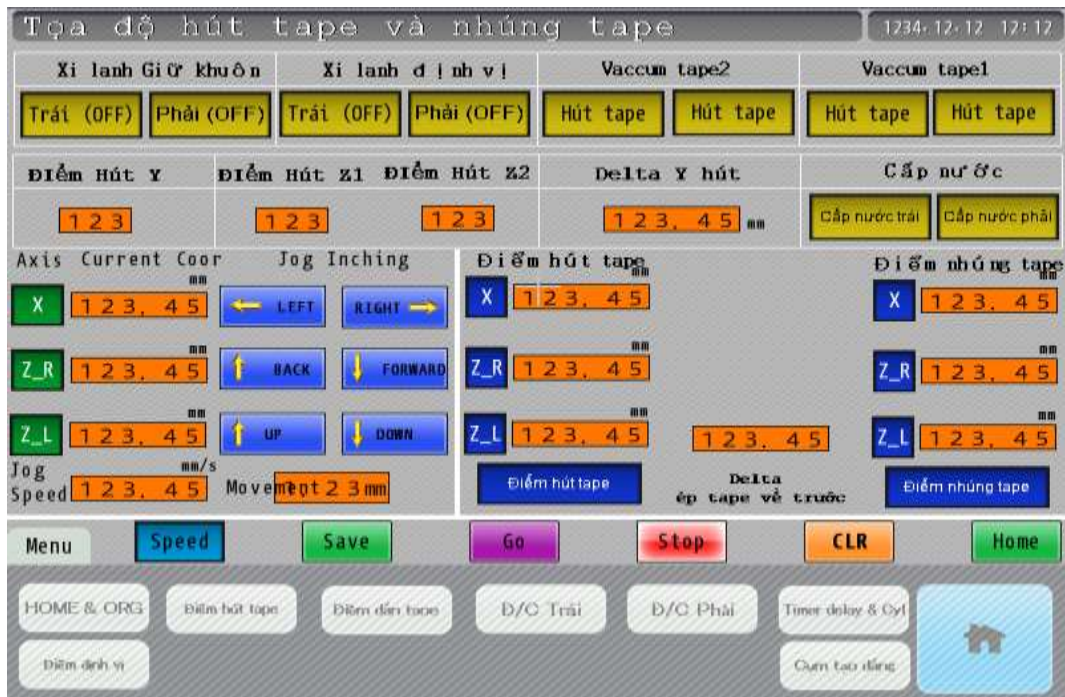


Figure 3.20 Robot coordinate setting screen

To set the tape suction point, first jog the robot to the location to be set, then select the tape suction point button and hold down the 'save' button. The coordinates will be automatically saved or you can enter the coordinates directly.

To let the robot run to the set position, select the "Tape suction point" button, then hold down the "Go" button and the robot will go to the set position. Click the "Speed" button to set the speed for the shaft.

- ❖ Note: When pressing to run the tape suction point, pay attention to the Y-axis suction point and the 2 Z-axis suction points to avoid machine collision.

Similar settings for the remaining robot points



Figure 3.21 Timer Delay Screen

With the timer delay page, in addition to the timer delay values for each task, we have 2 notes.

- z-axis travel limit, is the deepest coordinate at the suction position that we allow the robot to go down
- The number of Z points down here means. The number of times the Z coordinate goes down from the first suction point to the Z axis travel limit point, and the displacement of each time sec takes the travel limit from the suction coordinate 1 divided by the number of times Z goes down.

CHAPTER 4: Results

4.1 Overview of the Three Tested Options

During the research and development phase of the tape-wrapping machine for voice coils, three mechanical design options were proposed and presented in Chapter 2. In order to determine the most suitable solution for practical manufacturing, all three options were fabricated, assembled, and tested under identical conditions, using the same product type, control system (PLC and drivers), operating environment, and quality inspection procedure.

Objectives of the Testing

- To evaluate the real-world performance of each design option
- To assess stability, accuracy, and overall tape application effectiveness
- To analyze the causes and frequency of defects
- To select the most optimal design for mass production

Testing Methodology

- Each option was tested over eight consecutive days, with a consistent output of 200 products per day, totaling 1,600 products per design.
- After the machine completed each tape-wrapping cycle, the resulting product was inspected and categorized as either OK (passed) or NG (defective).
- Each NG product was classified based on the type of error, including:
 - Tape misalignment
 - Cross tape
 - Two tape edges do not overlap
 - Two tape suction
 - Tape suction error
 - Can't suck tape

Data Collection and Analysis

- Data was recorded daily and compiled into detailed statistical tables.
- The results include:
 - Total number of OK products per day
 - Total number of NG products per day
 - Error distribution by type
- After the test period, the data was analyzed to evaluate performance, operational consistency, and root causes of errors for each design.

The next sections will present a detailed breakdown of test results and performance analysis for each mechanical design option.

4.2 Analyze Errors

4.2.1 Tape misalignment

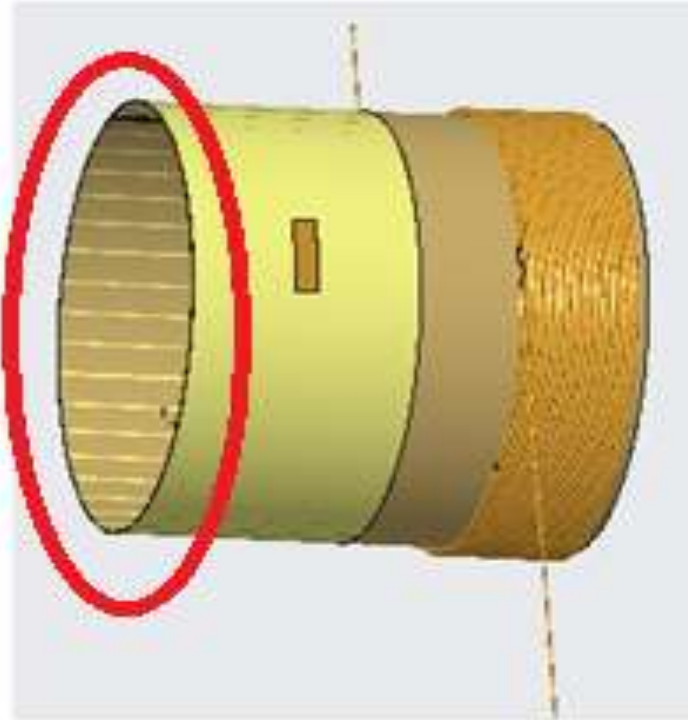


Figure 4.1 Tape misalignment

Tape misalignment occurs when the position of the tape is not aligned with the required specification, specifically when the tape is applied too close to the outer edge of the voice coil, as highlighted in red in the image.

According to design requirements, the outer edge of the tape must be positioned 0.8 mm inward from the edge of the voice coil to:

- Ensure proper alignment when the coil is assembled into the magnetic gap
- Prevent interference with diaphragm movement and mechanical clearances
- Maintain vibration accuracy during operation

However, in this error condition, the tape is misaligned too close to the edge, or in some cases, overhanging beyond the edge, which may lead to:

- Poor visual and dimensional quality
- Difficulties in assembly or interference with moving parts
- Risk of tape peeling due to insufficient bonding area

4.2.2 Cross tape

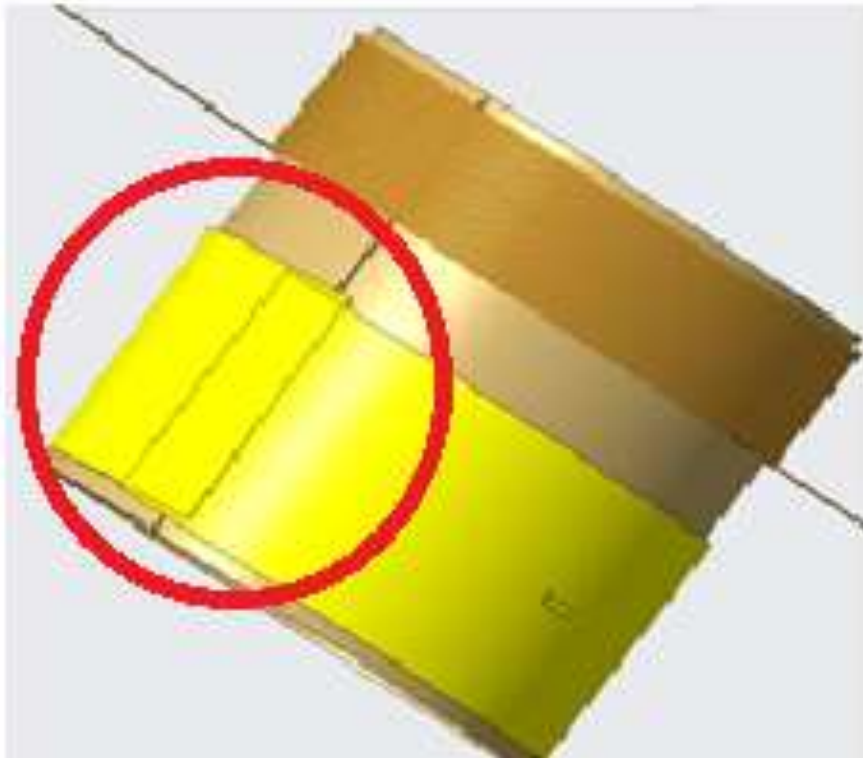


Figure 4.2 Cross tape

Error Description: Cross Tape

Cross tape occurs when the tape layers do not align evenly after application, resulting in a misalignment along the horizontal axis, where the tape overlaps unevenly or shifts during wrapping, as highlighted in red in the image.

According to the technical specifications, the tape wraps around the voice coil must be precisely aligned edge-to-edge, forming a flat and uniform surface to ensure:

- Maximum adhesion between tape layers
- Roundness and mechanical balance of the voice coil
- No interference with the coil's movement within the magnetic gap

In this error condition, the tape shifts or overlaps incorrectly, causing:

- Tape wrinkling, folding, or incomplete adhesion
- Local thickness variation, which may lead to fitting issues when inserting into the magnetic gap
- Reduced durability and operating stability

4.2.3 Two tape edges do not overlap

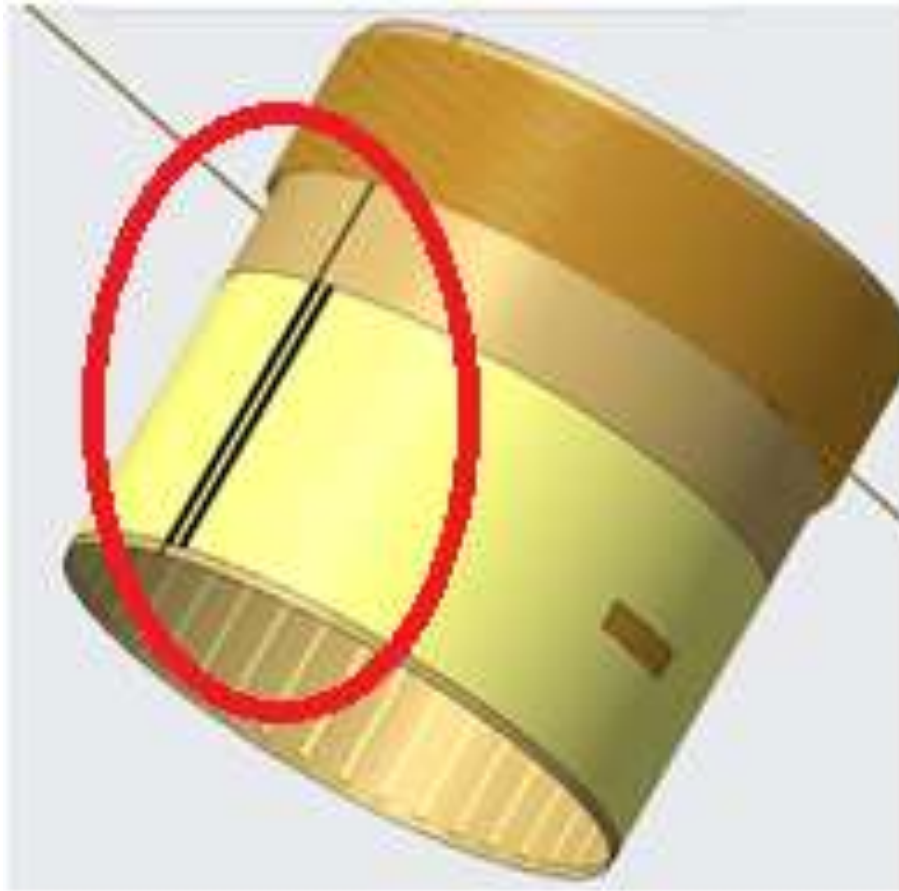


Figure 4.3 Two tape edges do not overlap

Error Description: Two Tape Edges Do Not Overlap

Two tape edges do not overlap refers to an error in which the two ends of the tape do not meet precisely along the predefined reference line after wrapping, resulting in a visible gap or misalignment between the tape edges, as highlighted in red in the image. According to technical requirements, the tape must be wrapped around the voice coil in such a way that both edges align perfectly with the designated reference mark, in order to:

- Ensure consistent adhesion across the entire circumference
- Prevent gaps or overlaps that can cause mechanical imbalance
- Maintain concentric alignment of the copper windings on the voice coil, avoiding shifts that may affect the magnetic field or cause physical interference during operation

In this error condition, the tape ends fail to meet at the marked position, leading to:

- Exposed or overlapping tape seams, creating structural weaknesses
- Misaligned copper layers around the coil, causing off-center winding
- Potential impact on sound quality and vibration stability during use

4.2.4 Two tape suction

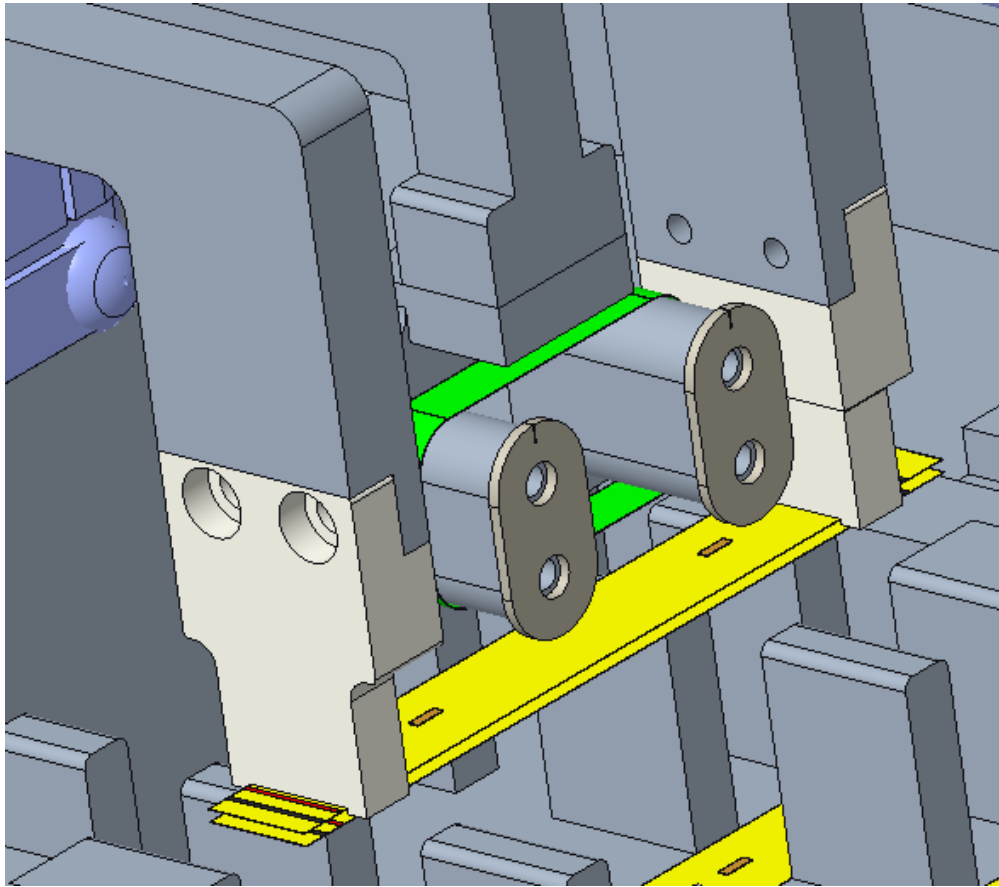


Figure 4.4 Two tape suction

Error Description: Two Tape Suction

Two tape suction occurs when the robot arm equipped with the suction mechanism unintentionally picks up two tape pieces at once, instead of just one as intended.

In normal operation, the robot moves down to the tape tray or tape holder and uses vacuum suction to pick up a single piece of tape. However, due to mechanical or surface-related issues, two pieces of tape may stick together or be picked up simultaneously, resulting in incorrect tape handling.

Consequences of the Error:

- When the tape is applied, two overlapping layers cause increased thickness, leading to misalignment or poor aesthetics
- May cause jamming during the tape pressing or rolling process
- In some cases, the lower layer may not adhere properly and could peel off later in production

4.3. Performance results of each design option

4.2.5 Can't suck tape

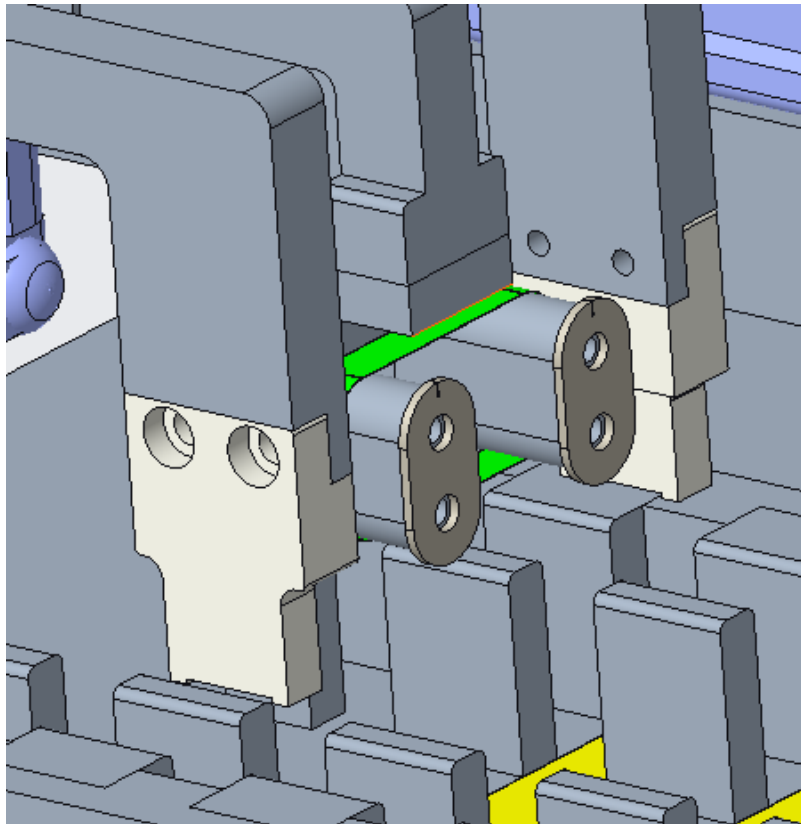


Figure 4.5 Can't suck tape

Can't suck tape refers to an error where the tape suction head moves down to the correct pickup position but fails to lift the tape. After attempting suction, the head does not hold any tape for the next application step.

Consequences of the Error:

- The tape application process is interrupted; the robot returns without a tape
- Results in missing tape on the product, severely affecting quality
- May cause system malfunction if the machine doesn't detect the missing tape

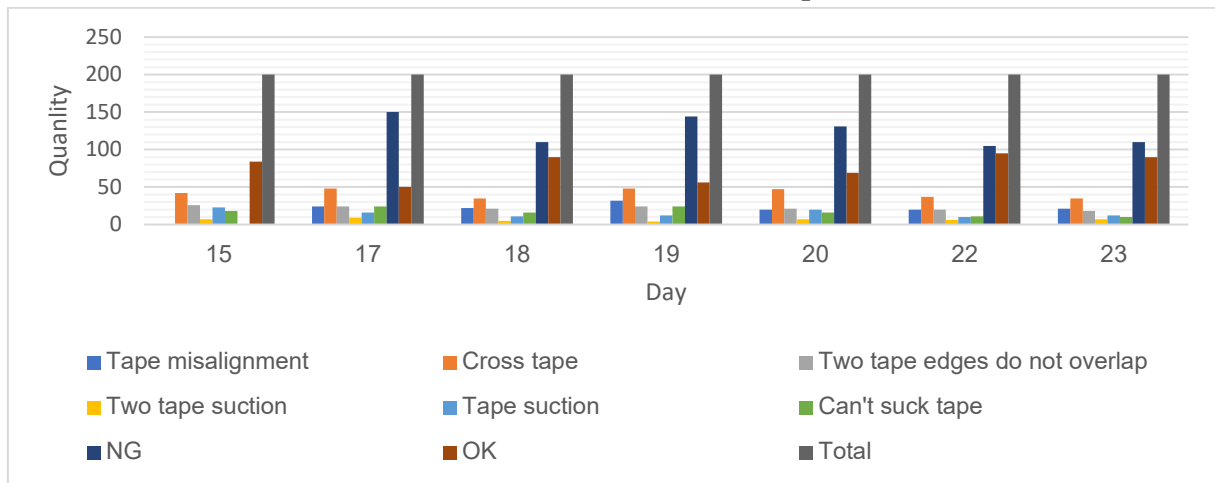
4.3.1 Result of design option 1

After conducting real-world testing for all three mechanical design options under identical conditions, the collected data clearly reflected the differences in performance and stability among the options. The results for each option are summarized as follows:

Table 4.1 Statistical table of test results of option 1 in march

D	15	17	18	19	20	22	23
Tape misalignment	25	24	22	32	20	20	21
Cross tape	42	48	35	48	47	37	35
Two tape edges do not overlap	26	24	21	24	21	20	18
Two tape suction	7	9	5	4	7	6	7
Tape suction	23	16	11	12	20	10	12
Can't suck tape	18	24	16	24	16	11	10
NG	116	150	110	144	131	105	110
OK	84	50	90	56	69	95	90
Total	200	200	200	200	200	200	200

Chart 4.1 Test run result chart of option 1



Evaluation of the First Design Option

The first mechanical design option was tested from March 15 to March 23, with a total of 1,400 products evaluated. The results showed insufficient performance, high defect rates, and low consistency—all of which fall short of the standards required for mass production deployment.

1. Defect Rate (NG)

- Total number of defective (NG) products: 862 units, accounting for 61.6%
- Day with the lowest defect count: March 22, with 105 NG units (52.5%)
- Day with the highest defect count: March 17, with 150 NG units (75%)
- The defect rate fluctuated significantly (from 52.5% to 75%), indicating poor operational stability

2. Common Defects

- Cross tape was the dominant defect, occurring at a consistently high rate—35 to 48 cases per day—indicating that the tape alignment and application angle were not properly controlled

- Other recurring defects included tape misalignment, non-overlapping tape edges, and can't suck tape, each appearing 20–30 times daily, pointing to inaccurate positioning and unstable suction performance
- Two tape suction and tape suction errors also occurred regularly, suggesting that the vacuum system and tape feeding mechanism were not optimized, leading to either double pickup or failure to adhere properly

3. Accepted Products (OK)

- Total number of OK products: 538 units, accounting for 38.4%
- Best performance was on March 22 with 95 OK products (47.5%)
- Worst performance was on March 17 with only 50 OK products (25%)
- Overall, the success rate was extremely low, with many days falling below 50%, which is far below acceptable thresholds for production readiness

Preliminary Conclusion

The first mechanical design option had the poorest performance among the three tested:

- Defect rate exceeded acceptable limits (>60%)
- Large daily fluctuations, indicating system instability
- Major recurring issues such as cross tape, misalignment, and failed suction

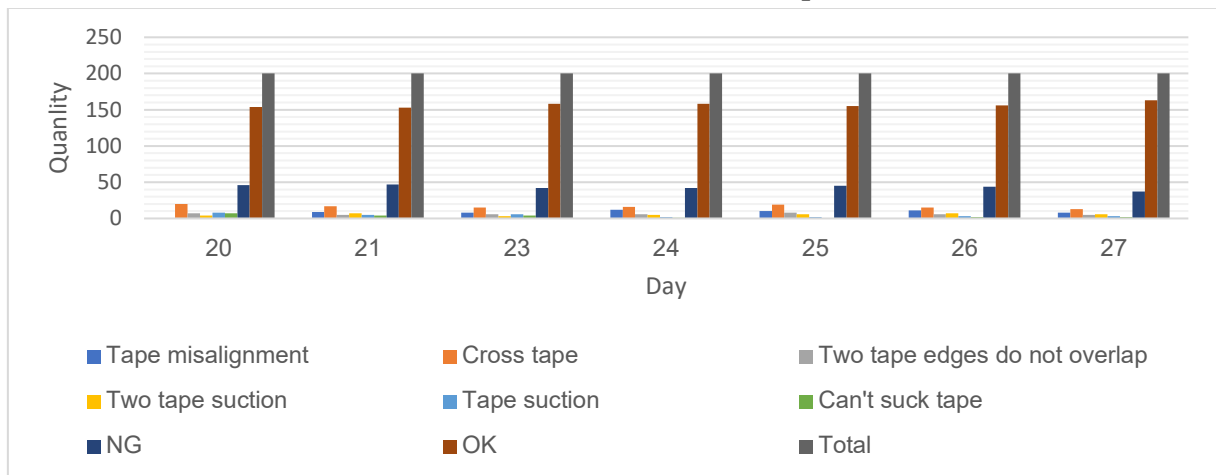
=> With option 1, we see that Cross tape errors occur frequently. Realizing that, the group found the cause was that the tape container had a shape that was not suitable for the tape paper, causing the tape to shift easily, leading to misalignment when sucking. Another reason was that when sucking the tape up, the group noticed that the tape was wrinkled and not flat. Therefore, the group thought and designed the second option, which was to change the tape supply container and add a tape-flat suction mechanism.

4.3.2 Result of design option 2

Table 4.2 Results table after 1st improvement

D	20	21	23	24	25	26	27
Tape misalignment	10	9	8	12	10	11	8
Cross tape	20	17	15	16	19	15	13
Two tape edges do not overlap	7	5	6	6	8	6	5
Two tape suction	4	7	3	5	6	7	6
Tape suction	8	5	6	2	2	3	3
Can't suck tape	7	4	4	1	0	2	2
NG	46	47	42	42	45	44	37
OK	154	153	158	158	155	156	163
Total	200	200	200	200	200	200	200

Chart 4.2 Test run result chart of option 2



Evaluation of the Second Design Option

The second mechanical design option was tested from April 20 to April 27, with a total of 1,600 products evaluated. The results showed stable performance, low defect rates, and high repeatability—all of which are essential factors for a system intended for mass production.

1. Defect Rate (NG)

- Total number of defective (NG) products: 343 units, accounting for 21.4%
- Lowest defect count: April 27, with 37 NG products (18.5%)
- Highest defect count: April 21, with 47 NG products (23.5%)
- The fluctuation was small (around $\pm 2.5\%$), indicating good operational stability throughout the test period

2. Common Defects

- Cross tape remained the most frequent error, but was significantly reduced to only 13–20 defects per day, much lower than in previous designs
- Other errors such as tape misalignment, non-overlapping tape edges, and two tape suction remained low (under 10 per day), showing high mechanical accuracy in alignment and tape placement
- Suction-related issues such as tape suction and can't suck tape were minimal, often only 0–2 cases per day, confirming that the suction system had been well optimized

3. Accepted Products (OK)

- Total number of OK products: 1,257 units, accounting for 78.6%
- All days maintained over 150 OK products per day
- Best performance was on April 27, with 163 OK products (81.5%)
- The OK rate remained consistently high, demonstrating reliable production efficiency

Preliminary Conclusion

The third mechanical design option demonstrated stable and high-quality performance, standing out with:

- Low defect rate (~21%)
- Excellent consistency across all test days
- Minimal critical errors such as suction failures or tape misalignment

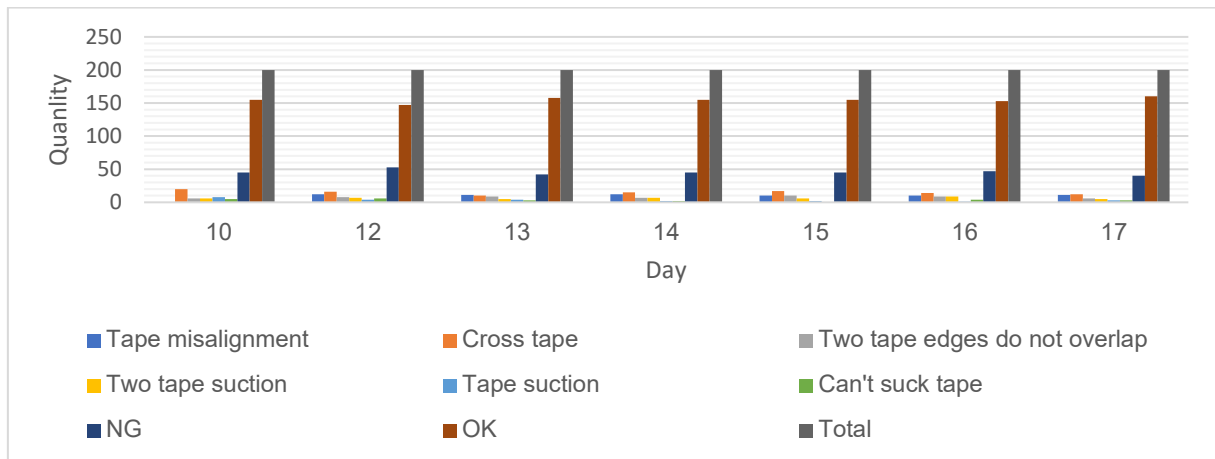
=> After improving the tape container design and adding a tape flattening mechanism, the machine running results were clearly different. In general, we saw that all errors were reduced, especially the cross tape error was significantly improved. Besides, other errors still occurred, so the team decided to design a third option to try to improve it. This design meets technical and production requirements well and can be selected as the final version for practical implementation or production scale-up.

4.3.3 Result of design option 3

Table 4.3 Data statistics table after the second machine improvement

D	10	12	13	14	15	16	17
Tape misalignment	10	12	11	12	10	10	11
Cross tape	20	16	10	15	17	14	12
Two tape edges do not overlap	6	8	9	7	10	9	6
Two tape suction	6	7	5	7	6	9	5
Tape suction	8	4	4	2	2	1	3
Can't suck tape	5	6	3	2	0	4	3
NG	45	53	42	45	45	47	40
OK	155	147	158	155	155	153	160
Total	200	200	200	200	200	200	200

Chart 4.3 Test run result chart of option 3



Evaluation of the Third Design Option

The third mechanical design option was tested from May 10 to May 17, with a total of 1,600 products inspected. The results indicate that this option delivered relatively high efficiency, an acceptable defect rate, and consistent performance across all testing days, making it a suitable candidate for real-world implementation with minor adjustments.

1. Defect Rate (NG)

- Total number of defective (NG) products: 367 units, accounting for 22.9%

- Lowest defect count: May 17, with 40 NG products (20%)
- Highest defect count: May 12, with 53 NG products (26.5%)
- Daily variation in defect rate was approximately $\pm 3.25\%$, indicating fairly good consistency

2. Common Defects

- Cross tape remained the most frequent issue, but was significantly reduced compared to Option 1, ranging from 10–20 defects/day
- Other issues like tape misalignment, non-overlapping tape edges, and two tape suction remained low and stable (under 10 defects/day), showing improved control over tape positioning and application force
- Suction-related errors like tape suction and can't suck tape were minimal, typically 0–5 cases/day, indicating that the suction system operated more reliably

3. Accepted Products (OK)

- Total number of OK products: 1,233 units, accounting for 77.1%
- All days recorded more than 145 OK products
- Best result was on May 17, with 160 OK products (80%)
- The OK rate remained steady, indicating strong and reliable production efficiency

Preliminary Conclusion

The second mechanical design option showed considerable improvements:

- Significantly lower defect rate ($\sim 23\%$) compared to Option 1
- Substantial reduction in cross tape and suction-related issues
- Stable OK output above 77%, with minimal daily fluctuation

=> After redesigning the tape pressure mechanism, the machine running results were not improved compared to the previous plan, but with this design, if running other products in the future, there is no need to redesign the tape pressure mechanism. This option is highly feasible for real production use and can be further refined by improving tape head alignment and suction positioning control.

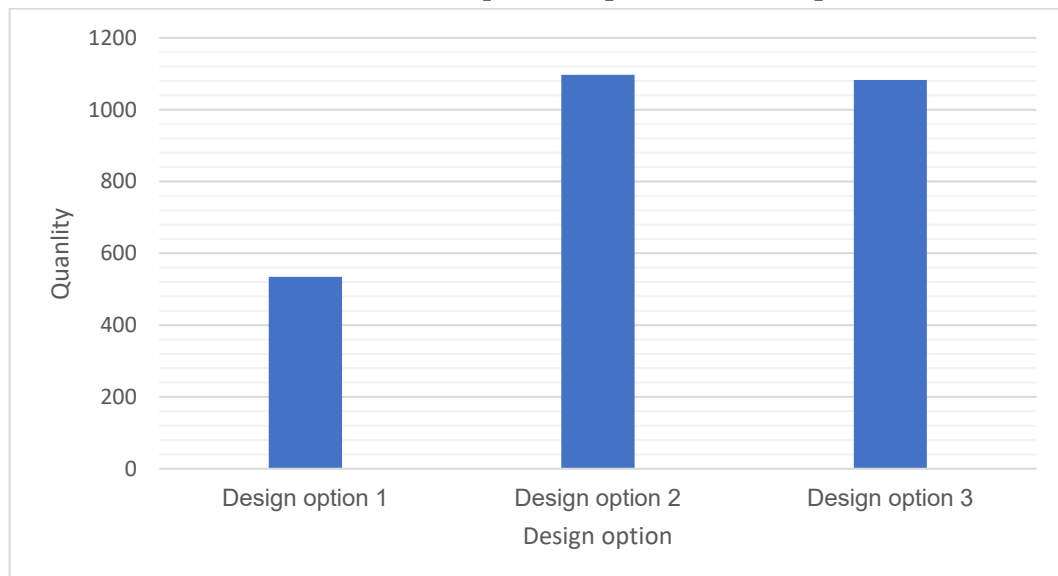
4.3.4 Compare the results of the three options

After conducting real-world testing for all three mechanical design options, the collected data revealed clear differences in performance, stability, and defect rates. The following table summarizes the key indicators:

Table 4.4 Compare the results of the 3 options

Criteria	Option 1	Option 2	Option 3
Test period	March 15–23, 2025	April 20–27, 2025	May 10–17, 2025
Total products tested	1,400	1,400	1,400
Total OK products	538	1,257	1,233
Total NG products	862	143	167
Defect rate (%)	61.6%	10.21%	11.92%
OK rate (%)	38.4%	89.79%	88.08%
Most frequent defects	Cross tape, can't suck tape	Cross tape	Cross tape
Daily fluctuation	Very high (25–75% OK/day)	Very stable (153–163 OK/day)	Moderate (147–160 OK/day)
Overall operational stability	Low	Highly stable	Highly stable

Chart 4.4 Number of qualified products of 3 options



Remarks:

- Option 1 had the highest defect rate and the largest fluctuation in daily performance, indicating instability in the mechanical structure and suction mechanism. Significant improvements would be required before practical deployment.
- Option 2 showed marked improvement, with a noticeable reduction in defects and higher productivity. Although cross tape errors persisted, its overall stability and efficiency were significantly better.

- Option 3 has a fairly low error rate but not as much as option 2. In terms of quality, option 2 will give better results, but if we consider the level of improvement for other products, option 3 will have the advantage. Because when the product diameter changes, the machine can still run without having to redesign the tape assembly.

From the machine running results table, the following comments are made:

- *Advantage:*
 - The machine can work and paste the goods effectively.
 - Compact and efficient machine structure.
- *Disadvantages :*
 - There are still many defective products, errors such as pasting tape orders, pasting tape crosswise, pasting two edges of tape not being loose together occur a lot.
 - The process of taking tape from the tape container still has errors such as sucking tape orders, placing tape in a diagonal and ordered position, the final tape will be difficult to take.

⇒From the process of running the system, it was observed that errors such as tape crossover, tape command and tape edge pasting are not the same, which still occurs a lot, causing the machine's efficiency to only reach about 35%. The above errors are predicted by the group to come from two main causes. The first is from the tape feeding cluster to the pasting position and the second is from the tape overlay cluster. From there, the group will deploy option 2 to improve the system to minimize and fix errors.

4.4 Future Works

To solve the problem when the Gmail device sucks 2 tapes at a time, the group has an idea of a mechanism to be able to take 1 tape at a time out of the jar. So when sucking, only 1 tape is sucked. The mechanism will include 1 push cylinder and 1 suction cylinder described as the 3D image below.

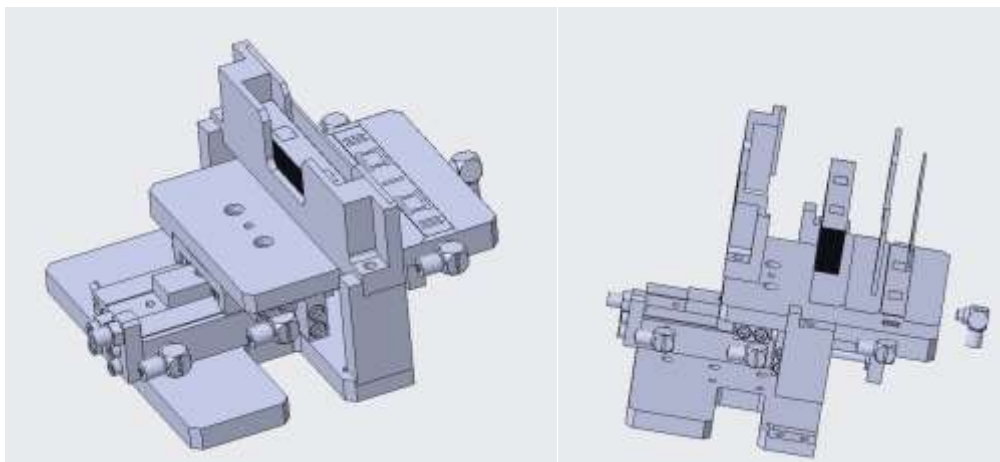


Figure 4.7 Improved tape assembly

This plan has only been implemented by the group with ideas and design of replacement parts, not yet assembled into the machine and tested on a real model. Due to lack of time. Design and test ideas one tape at a time.

CHAPTER 5: Conclusion

5.1 Conclusion

During internship at Foster Company was an extremely valuable period, marking an important turning point in my learning and professional development journey. During this time, I had the opportunity to directly participate in a real project: designing and completing an automatic tape dispenser - a device serving the production line in an industrial environment with high precision and stability requirements.

The project titled "Design and Fabrication of an Automatic Tape-Wrapping Machine for Voice Coils" was carried out with the objective of replacing manual taping processes with an automated system, aiming to improve accuracy, reduce defects, and enhance productivity and consistency in mass production of voice coils at Foster Company.

Throughout the research and implementation process, I developed and tested three different mechanical design options, integrated with a Keyence PLC-based control system, to determine the most optimal solution. All three designs were fabricated, assembled, and tested under identical operating conditions, followed by data collection and performance analysis.

The test results demonstrated that Design Option 3 was the most optimal, meeting key performance criteria:

- Number of OK products: 1,257 out of 1,600, equivalent to 78.6%
- Average defect rate (NG): only 21.4%, the lowest among all three designs
- Stable operation with minimal variation in performance across test days
- Accurate and efficient suction and tape application mechanisms

In addition to Option 3, Design Option 2 also delivered relatively high efficiency, proving that all proposed designs were practically feasible, requiring only minor adjustments for full optimization.

Through this project, I had the opportunity to apply specialized knowledge to real-world practice, including:

- Mechanical part design (using SolidWorks)
- PLC programming with Keyence systems
- Machine assembly, operation, error tracking, and data analysis
- Proposing improvements for better system performance

The project successfully fulfilled its intended goals and offers a practical and effective automation solution for the tape-wrapping process in voice coil manufacturing. It also provides a strong foundation for future enhancements and industrial-scale deployment.

5.2 Limitations

Although the project achieved promising results and met its intended objectives, there were still some limitations observed during implementation and testing, as outlined below:

- Common errors such as cross tape and tape misalignment continued to occur, especially during initial test phases. While these were significantly reduced in the optimized design, they were not completely eliminated.
- No automatic inspection system was integrated to verify the tape condition after application. Quality assessment still relied on manual observation, which reduced consistency and accuracy in inspection.
- The mechanical design lacked high flexibility, as each version was tailored to a specific voice coil size. Switching to different product types would require manual adjustments or partial redesign of components.
- There was no real-time error detection mechanism during the taping process. Issues like double tape suction or misaligned tape were not automatically identified or corrected using sensors or cameras.
- Testing was limited in scope, and long-term durability, wear of components, or multi-shift continuous operation in real production environments was not yet evaluated.

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