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RUHR-UNIVERSITÄT BOCHUM

MechEng
Mechanical Engineering



Vietnamese-German University

Conceptual design and prototype development of unwind and rewind system for web printing system

Bachelor Thesis

BINH DUONG, 2023



Vietnamese-German University

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CONCEPTUAL DESIGN AND PROTOTYPE DEVELOPMENT OF UNWIND AND REWIND SYSTEM FOR WEB PRINTING SYSTEM

A Thesis Presented

By

NGO HOANG QUAN

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CONCEPTUAL DESIGN AND PROTOTYPE DEVELOPMENT OF UNWIND
AND REWIND SYSTEM FOR WEB PRINTING SYSTEM



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AFFIRMATION IN LIEU OATH

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Title of thesis: CONCEPTUAL DESIGN AND PROTOTYPE DEVELOPMENT OF
UNWIND AND REWIND SYSTEM FOR WEB PRINTING SYSTEM

I hereby declare in lieu of oath that I have produced the aforementioned thesis independently and without using any other means except the aids listed. Any thoughts directly or indirectly taken from somebody else's sources are made discernible as such.

To date, the thesis has not been submitted to any other board of examiners in the same or a similar format and has not been published yet.



Binh Duong, April 26th, 2023

Signature

ABSTRACT

Main goal of this project is to create a prototype of a rewind and unwind system, which is an essential component in a web printing system. Web printing systems are commonly used in industrial factories to produce variables of product.

The prototype must be reliable and functional in a bigger system as a whole. The system has to be easy to replace the raw material and finished products, which means putting an empty roll in before the process and taking the roll out after it has been printed.



AUTHORSHIP STATEMENT

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LIST OF ABBREVIATIONS

Parameter		Units
R_u	Operating radius of the unwind roll	m
R_{u0}	Initial radius of the unwind roll	m
R_r	Operating radius of the rewind roll	m
R_{r0}	Initial radius of the rewind roll	m
J_u	Total moment of inertia of the unwind roll	kgm ²
J_{u0}	Initial total moment of inertia of the unwind roll	kgm ²
J_r	Total moment of inertia of the rewind roll	kgm ²
J_{r0}	Initial moment of inertia of the rewind roll	kgm ²
ω_u	Angular velocity of the unwind roll	rad/s
Θ_u	Rotational angular of the unwind roll	rad
ω_r	Angular velocity of the rewind roll	rad/s
Θ_r	Rotational angular of the rewind roll	rad
c_u	Coefficient of viscous friction of the unwind roll	Nms
c_r	Coefficient of viscous friction of the rewind roll	Nms
M_u	Torque applied to the unwind roll	Nm
M_r	Torque applied to the rewind roll	Nm
T	Web tension	N
L	Total length of web	m
E	Elasticity of the web	N/m ²
S	Cross sectional area of the web	m ²
h	Thickness of the web	m
w	Width of the web	mm
ρ	density of the web	kg/m ³
K_{su}	Shaft stiffness of the unwind roll	Nm/rad

K_{sr}	Shaft stiffness of the rewind roll	Nm/rad
c_{su}	Coefficient of vicious friction of the unwind motor	Nms/rad
c_{sr}	Coefficient of vicious friction of the rewind motor	Nms/rad
Θ_{mu}	Rotational angular of the unwind motor	rad
ω_{mu}	Angular velocity of the unwind motor	rad/s
Θ_{mr}	Rotational angular of the rewind motor	rad
ω_{mu}	Angular velocity of the rewind motor	rad/s
M_{mu}	Torque generated by the motor at unwinder	Nm
M_{mr}	Torque generated by the motor at rewinder	Nm
a	Distance from support point	m
M	bending moment on the roller	Nm

CHAPTER 1: Introduction

1.1/ Background study

1.1.1/ Brief introduction about web printing, rewind and unwind system

Web printing has been an important part of the human's history. Printing technique has been used in ancient China since 200AD. This technique was used later in Europe, around 1400. However, there is only woodblock printing around this time. In 1440, a new printing method was invented by Johann Gutenberg. This is an essential evolution of printing methods, and human's history. This allowed the lower class to gain access to the knowledge due to the lower price of books. Different techniques were invented later in the 1515 and 1790s. The rotary press printing technique was invented in 1873 by Richard March Hoe. Rotary press was an important step for modern printing technology as it can print faster due to the fact that the paper was fed through the press continuously.

In 1875, Offset Printing was invented and it is still used nowadays. The most common usage of Offset Printing is to print large format printing.



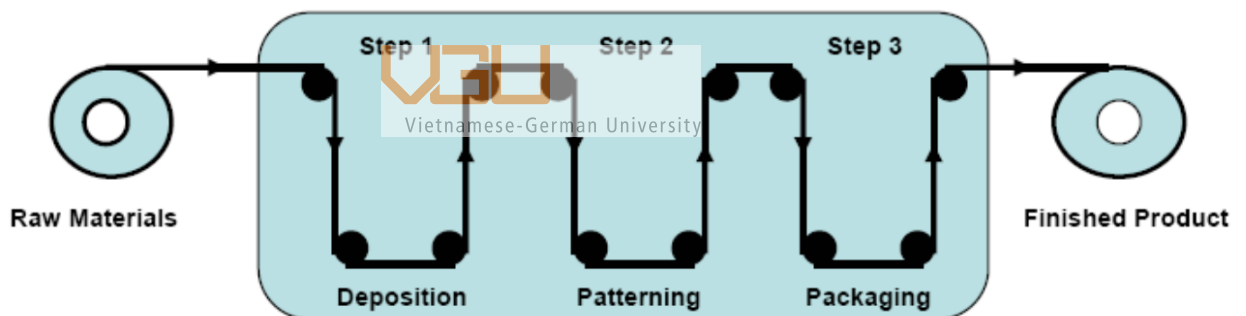
In the next 100 years, the technology for web printing improved a lot and we got what is used nowadays in the printing industry.

This technology has advanced to the point where it could be used to print even electrical devices. Nowadays, not only books, magazines and newspapers are printed, there are different familiar things we use everyday, such as labels of bottles, and even electrical equipment are printed. Having things printed makes the production cost lower and faster since it can be printed in large numbers. This improves the overall quality of life.



Figure 1. An example of industrial printing system

Figure 2 shows a printing process of labels using a printing machine from Konica Minolta. The labels can be printed in different color schemes, making the value of products increase.



Roll-to-roll manufacturing process flow

Figure 2. Overview printing process

In a web printing machine, there are two parts which take the responsibility for feeding the raw material and collecting the finished products. They are called rewind and unwind systems. These two systems include a motor that is used to run the system, a roller functions as the center of the roll material. It also has other components that support the performance of this system. These components are a coupling and a rod that transmit the force from the servo motor to the roller.

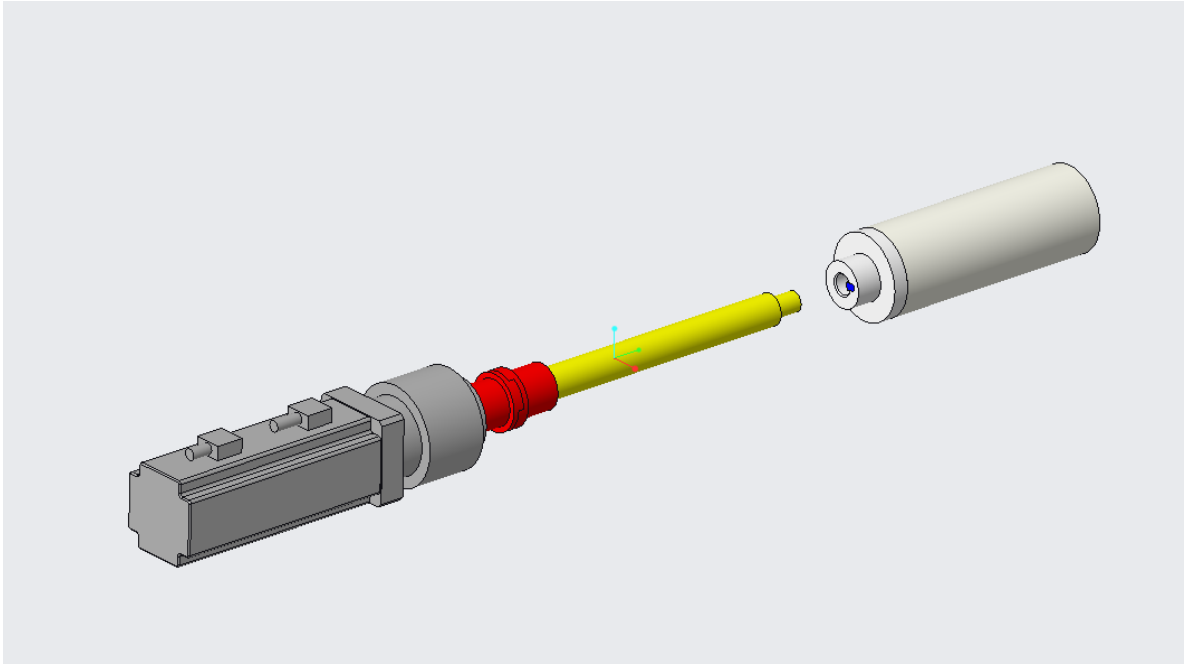


Figure 3. Main components of rewind and unwind systems

Function of each component in this design are:

- Motor: receive information from the controller and generate torque for systems performance.
- Coupling: receive torque from the motor and transmit it to the connecting rod while reducing the vibration and allowing some degree of misalignments to be able to work properly.
- Connecting rod: transmit torque from the coupling to the roller.
- Roller: the center of a material and product roll, responsible for working directly with the material and product.

Apart from the part mentioned above, there are other components for supporting these components, which will be discussed later.

1.1.2/ Brief idea for the design of rewind and unwind systems

The requirement for design is that the systems need to be able to handle the performance of the web printing machine, as well as being consistent while doing its job. The second requirement of this project was to make the system in a way that it would be easy to remove the final product and insert new raw material.

According to the requirements above, the design that only holds the roller on one side for the easy to remove product and insert raw material. However, the problem with this design is that the balance of

the system is not consistent because of that arm. In order to solve this problem, the base and the holder have to be heavier. This design will become the counterbalanced weight to hold the roller and keep the consistency of the system while it works for a long period of time.

The design is simple so that it could be upgraded and fixed later when it is used. Therefore, the heavier materials are chosen instead of adding more detail to my design for the unwind and rewind systems.

1.2/ Research problem

The idea of creating a simple web printer for research and study purposes comes from how it is used in industry nowadays. A printer is a compilation of both mechanical and electrical systems in order to print products. In this project, only the mechanical components are taken into consideration. The programs which take the responsibility for controlling the rewind and unwind systems as well as other mechanical components of the web printing machine are prepared beforehand.

The goal of this project is to create a prototype of the rewind and unwind system that can hold the roll with around 5 kg of material or product. The rolls also need to be able to perform without bending for a long period of time, as it is used for researching purposes of future students while learning about PLC, which is the main component to control the whole system.

1.3/ Scope of implementation

The main objective of this thesis is to create a prototype for the rewind and unwind of a web printing system, also use it as a groundwork for future improvement. Included in this report is formulation, problem analysis and experiments for the design and implementation.

1.4/ Objectives

The intended result for this project is creating a conceptual design and also making a working prototype of the unwind and rewind system, as a part of the mechanical system that would be used for the web printing system. The goal of this project are:

- The rewind and unwind systems are able to work under the torque of 30 Nm.

- Vibration of this system needs to be minimized.
- There is no severe damage or broken component during the testing phase.
- The systems are movable.
- The systems are easy to disassemble and fix or upgrade.



CHAPTER 2: Mechanical design of rewind and unwind systems

2.1/ Introduction

The design of this project must be done following the practical purposes and safety requirements. The first step is to calculate and design the systems on the computer. After the design is done, Making the prototype from the raw material and assembling them together. Most of the dimensions for this project would be determined after having calculated them.

All the other parts for my thesis, which cannot be created from raw material by ourselves, have standard dimensions. These components are:

- servo motor
- Shaft bearing
- Roller
- Other essential parts such as bolts, nuts, etc.



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Apart from those other components, all other parts that needed to be calculated and design are:

- Frame to hold the servo motor.
- Connect rod between motor and roller.
- Frame to connect all other parts together.

The requirements for the parts that needed to be designed are:

- They need to be able to hold the whole system together.
- As the whole system, it needs to be able to support the weight and force that is created by the web printing system.

2.2/ Material selection and mathematical problem

2.2.1/ Material selection

Due to the requirement for rewind and unwind systems as a start point and endpoint of a web printing machine, it is necessary to be able to handle all the weight of the roller combined with the weight of the material and the forces created while the machine is running.

The easy to fix and easy to improve are two significant aspects of this design, that is why choosing a heavier material while also maintaining the shape of the design is a must for this project.

When this project started, the steel frame was chosen because it is sturdy and it can handle all the forces generated by the systems. However, steel is harder to work on due to its properties. After having considered this problem, aluminum was chosen as the material for the frame. It is not as sturdy as steel, but it is more flexible than steel and easier to work on.

According to the requirement above, the material choice for this system is steel for the connecting rod and the motor gear holder. The frame on the other hand would be created by using inox.

Steel does have properties that fit for the purpose of this project. It has density around 8000 kg/m^3 , and the yield strength is about 350 MPa , making it the perfect material in charge of handling the weight and force that the systems create.

On the other hand, aluminum does not have the properties to make it a sturdy material as steel. However, since the steel has been in charge of handling all the force created during the activity of the systems, the frame only needs to be strong enough to not let all the system that is placed on it fall to the ground. Aluminum is the most accepted material for this position. It has a density of around 2700 kg/m^3 .

2.2.2/ Mathematical problem

In order to have a system that works without any problem, having the system calculated carefully is an essential requirement. It is important to calculate all the parameters according to Newton's law and apply the principle of mass conservation.

$$\dot{\omega}_u = \frac{1}{J_u} \cdot M_u + \frac{R_u}{J_u} \cdot T - \frac{c_u}{J_u} \cdot \omega_u$$

$$\dot{\omega}_r = \frac{1}{J_r} \cdot M_r - \frac{R_r}{J_r} \cdot T - \frac{c_r}{J_r} \cdot \omega_r$$

$$\dot{T} = \frac{(T + E.S) \cdot R_r}{L} \cdot \omega_r - \frac{(2T + E.S) \cdot R_u}{L} \cdot \omega_u$$

Angular velocities and the radius of the rolls can be calculated by applying these equations:

$$\theta_u = \int_0^t \omega_u$$

$$\theta_r = \int_0^t \omega_r$$

These following equations can calculate the change of inertia

$$R_u = R_{u0} - h \cdot \frac{\theta_u}{2\pi}$$



$$J_u = J_{u0} + \pi \cdot \rho$$

$$J_u = J_{u0} + \pi \cdot \rho \cdot \omega \cdot \frac{(R_u^4 - R_{u0}^4)}{4}$$

$$J_r = J_{ur} + \pi \cdot \rho \cdot \omega \cdot \frac{(R_u^4 - R_{u0}^4)}{4}$$

Assume that motors can generate torque without including waste energy due to friction, etc. We can obtain the relationships between the value of the motors according to the first two equations by applying the law of energy conservation:

$$\dot{\omega}_{mu} = \frac{1}{J_{mu}} \cdot M_{mu} + \frac{1}{J_{mu}} \cdot M_u - \frac{c_{mu}}{J_{mu}} \cdot \omega_{mu}$$

$$\dot{\omega}_{mr} = \frac{1}{J_{mr}} \cdot M_{mr} - \frac{1}{J_{mr}} \cdot M_r - \frac{c_{mr}}{J_{mr}} \cdot \omega_{mr}$$

$$M_u = k_{su} \cdot (\theta_{mu} - \theta_u) + c_{su} \cdot (\omega_{mu} - \omega_u)$$

$$M_r = k_{sr} \cdot (\theta_{mr} - \theta_r) + c_{sr} \cdot (\omega_{mr} - \omega_r)$$

The aforementioned problems and equations will impact on the performance of the web printing machine directly. It may affect the longevity of the rewind and unwind systems, also the printing of the machine. If the paper is not stretched enough, the printing machine will not be able to work on the material. On the other hand, if the paper is stretched too much, there might be a case where the paper will eventually break and it will affect the rolls and the connecting rods of the rewind and unwind systems. We can refer to it as the dynamic of roll, or in other words, it is the interaction between rewinder and unwinder and the material while the machine is running. [2]

Another factor we need to consider is the effect of the roller to the rest components of rewinder and unwinder. We can obtain this factor by using the stress, strain, and beam bending values. In this case, we assume that the roller and the material roll is a rigid body.

Maximum shear stress of this can be calculated as:

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

The Working stress:

$$\sigma_e = \frac{S_{yt}}{FOS}$$

Yield stress, or in short S_{yt} is the characteristic of different materials. This factor is the line between a ductile and the brittle materials. In this project, a material with high S_{yt} is chosen due to the fact that it needs to handle a lot of force and moment created by the motors.

In the equivalent stress equation, we need to consider the factor of safety FOS. This number represents the maximum load that can be handled by the system. The FOS can be varied. If the FOS = 1.0, the system can not handle anything more than the design load of the system. If FOS = 2.0, it is possible to load twice the system design. In some cases, it is higher, such as pressurized fuselage in

the aerospace industry. Even though with the FOS too high, the aircraft would be too heavy to be able to lift. [1]

Choosing the Cartesian coordinates as the reference coordinates Ox,y,z for this project. With the design direction of the prototype, there will be no bending moment in y -direction:

$$\sigma_y = 0$$

As the bending moment in y -direction is equal to zero, the rest we need to consider is the bending moment in x,z -direction:

$$\sigma_x = \frac{M_b}{I_y} \cdot z$$

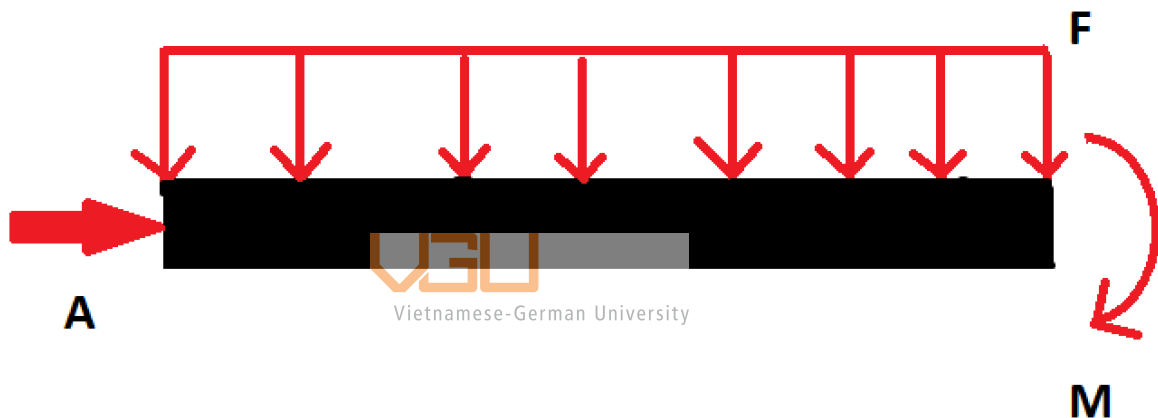


Figure 4. Freebody diagram of the bending moment on the roller

According to this freebody diagram, there is a support point on A point, the force F applied evenly on the roller. The analysis for force applied on the roller can be written as:

$$M - A \cdot x + F \cdot (x - a) = 0$$

Based on the equilibrium equations of the freebody diagram, we can calculate the bending moment of the roller as:

$$M = A \cdot x - F \cdot (x - a)$$

2.3/ Design and creating prototype for the project

2.3.1/ Frame for the rewind system

The base of the whole system, which has the responsibility to hold all the other components, is the frame. The first thing that needs to figure out when beginning to design this is what it would look like, how to make a prototype for it. The requirement for this frame that must be followed:

- It has to be able to hold the other components of the system together.
- The frame needs to be able to be mobility.
- It needs to be sturdy while the web printing machine is working.

At first, the idea of designing the frame for the system was still a question since there are different designs that also satisfy the requirement for this project. After having discussed carefully with my supervisor, the design of this system has been figured out more clearly. Below is the early image of the system, which acts as a foundation for the final design of the systems:

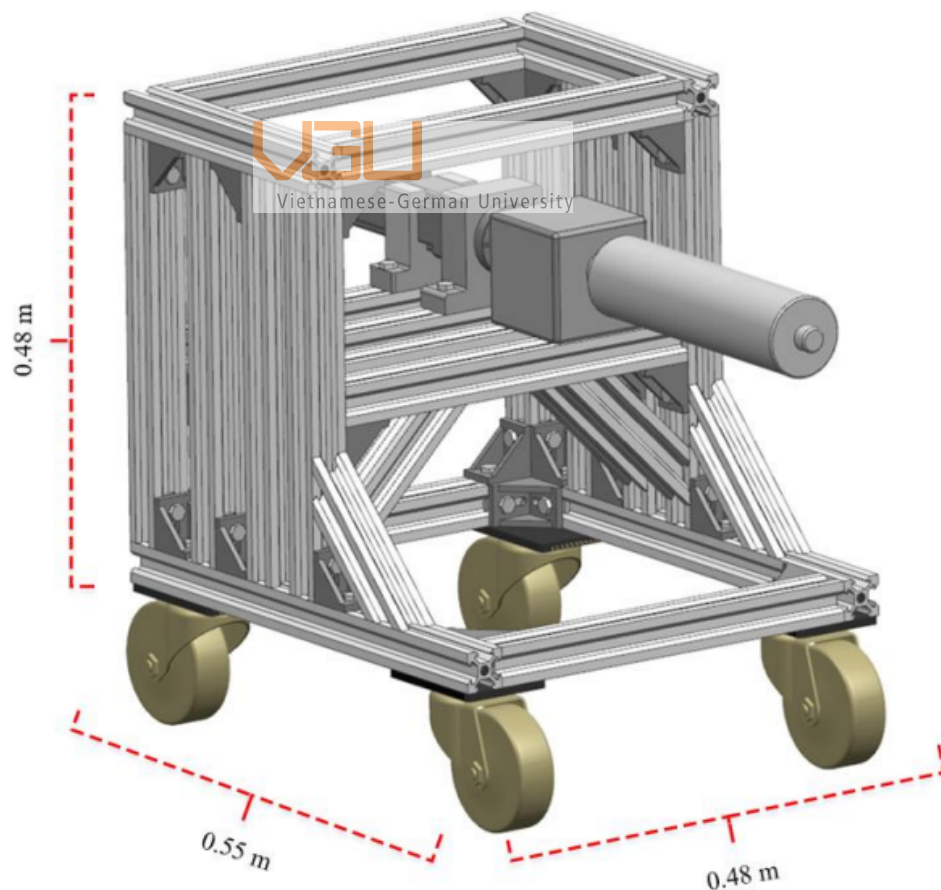


Figure 5. the early design of rewind and unwind system

From this first design for the frame, there are some other ways to change the design of this frame so that it would be more aesthetically pleasing. Instead of keeping the whole system of servo motor,

shaft bearing and roller inside the frame, they are held on the top of the frame for the purpose of easy disassembly and further improvement in the future.

This frame is made of aluminum alloy bars, which have pre-determined dimensions, in this case are 40 mm x 40 mm, the length can be changed to be fixed with the design of the frame. With this kind of aluminum bar, it weighs 1.25kg/m.

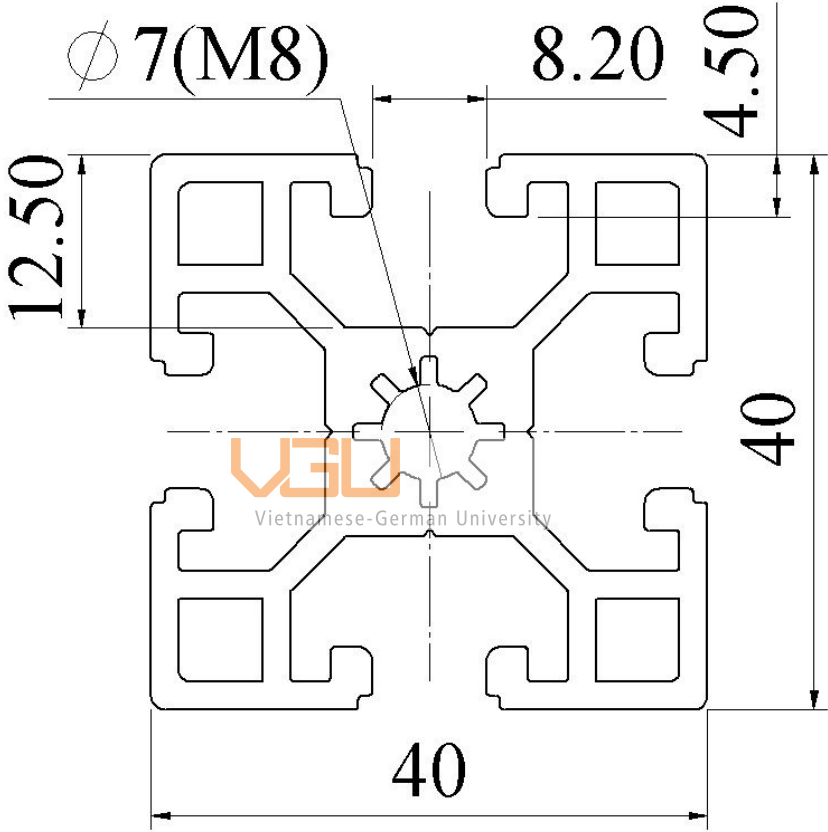


Figure 6. Design of an aluminum bar

The table below shows the specification of the frame after being assembled together:

Parameter	Value	Units
Length	520	mm
Width	520	mm
Height	325	mm
Weight	1.70625	kg

Volume	$0.6343 \cdot 10^{-3}$	m^3
--------	------------------------	-------

Table 1. Specification of the frame

After having all the bars cut the ideal size, it is connected together by using the Tabbed brackets. The aluminum bars do not come with the threads for screwing bolts, so we need other parts to completely connect the aluminum bars. It is called the Rear-loaded steel ball elastic nuts.



Figure 7. Tabbed brackets



Figure 8. Rear-loaded steel ball elastic nuts

In this project, most components are screwed on the aluminum bars so the Rear-loaded steel ball elastic nuts are utilized a lot during the assembly process. These nuts are installed between the aluminum bars before assembling the frame according to the design of the frame.

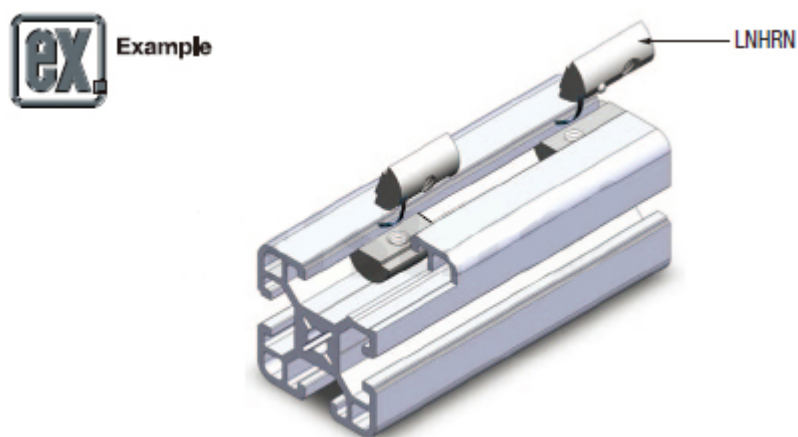


Figure 9. Installing the nuts

2.3.2/ Roller

The roller is a pre-made cylindrical round shape from aluminum, its weight is 5 kilograms. The main purpose of these two rollers are acting as the core for the material to roll around. On the one end of the roller is the connecting point between it and the rest of the system.

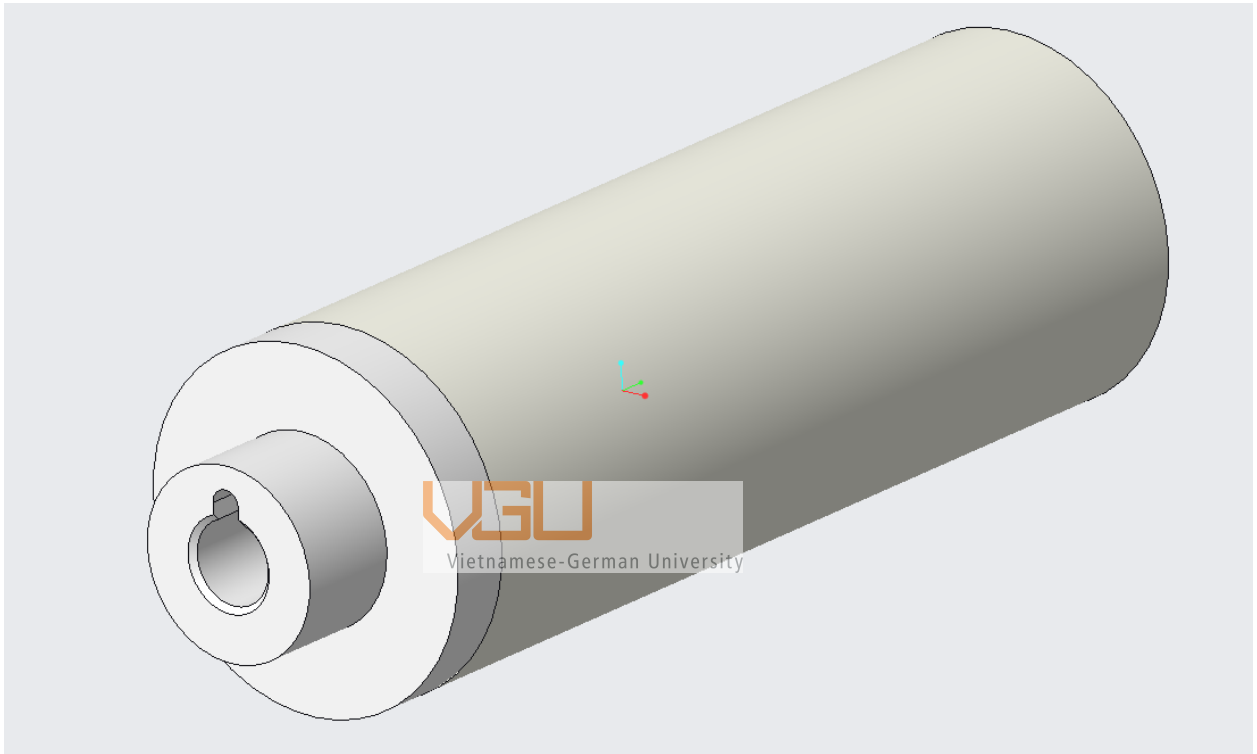


Figure 10. Design of the roller

The important part of this roller is the connecting part between the roller and the rest of the systems. With this design, it is possible to hold the roller and the connecting rod and reinforce so that it would not be

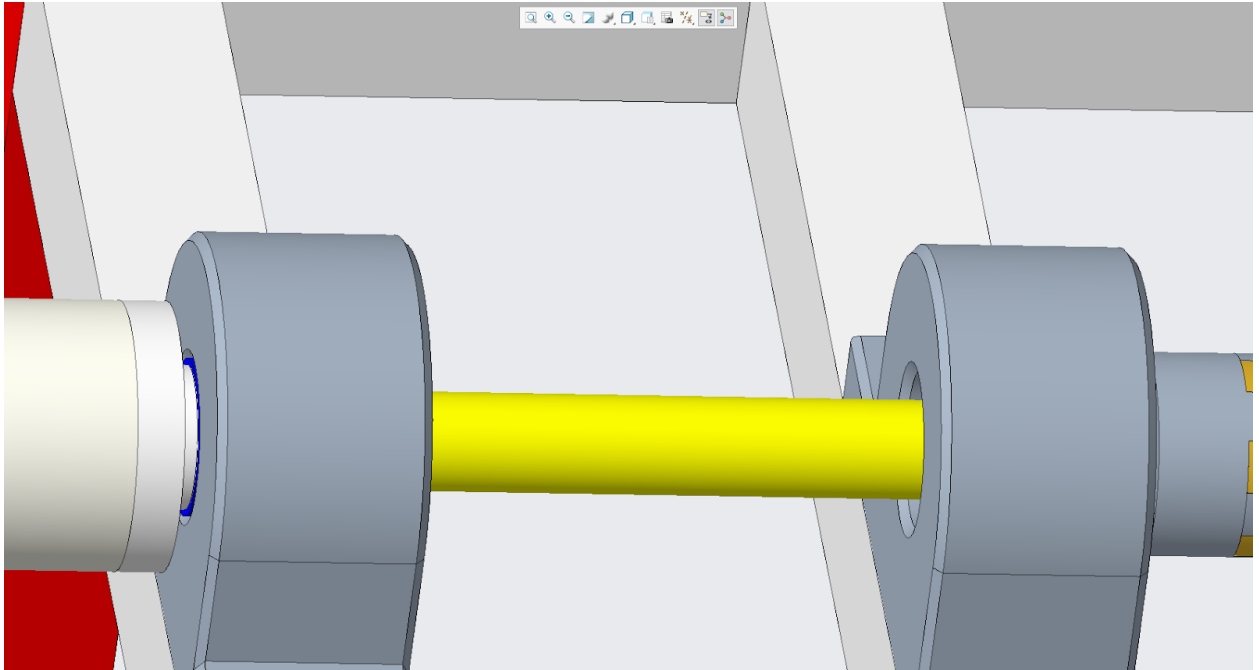


Figure 11. Connecting point between roller and the system

Holding the roller with the connecting rod together is a steel pin, while having both of them inside a shaft bearing for further reinforcement. This steel pin is also made from the same material with the connecting rod.



Figure 12. Design of the steel pin

The table below shows the specification of the steel pin:

Parameter	Value	Unit
Length	32	mm
Diameter	5	mm
Weight	0.005	kg

Table 2. Specification of the steel pin



2.3.3/ Connecting between servo motor and roller mechanism

2.3.3.1/ Connecting rod

While the servo motor and the roller are pre-made products, A connecting rod between them is the main focus of connection between them and it needs to be designed carefully.

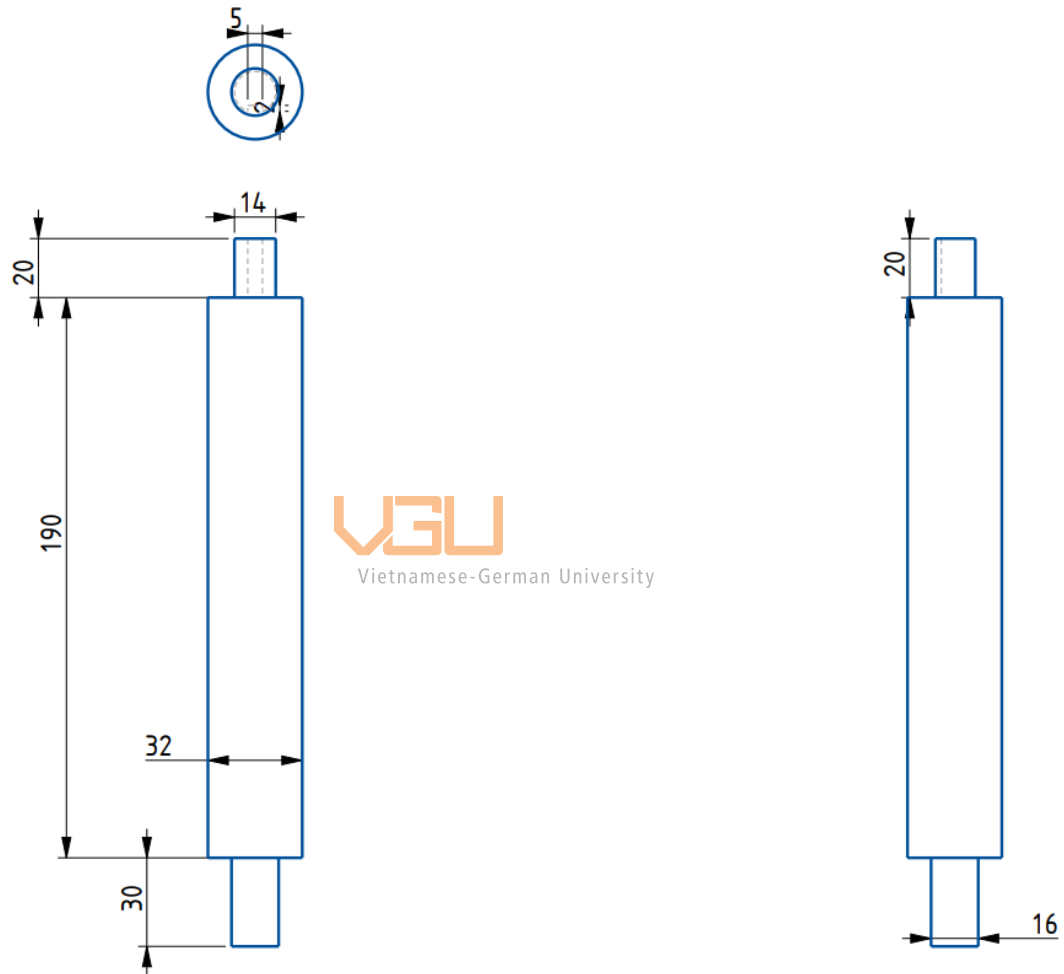


Figure 13. Blueprint of connecting rod

This connecting rod is also made from steel, the same material used for essential components that are responsible for keeping the system balance.

2.3.3.2/ Jaw Coupling

Between the motor and the connecting rod is a coupling. This coupling function is to transmit the turning force from the motor to the rod and furthermore to the roller. Having a coupling in this system gets a benefit, such as:

- Absorbing the vibration from the motor.
- Fixing the misalignment of the system, even just a little error while mounting can destroy the whole system.

The table below shows the specification of the connecting rod after it is processed:

Specification	Value	Units
Length	240	mm
Diameter 1	32	mm
Diameter 2	14	mm
Diameter 3	16	mm
Weight	1.26911	kg
Volume	$0.15864 \cdot 10^{-3}$	m^3

Table 3. Specification of the connecting rod

A jaw coupling is chosen to be used in this particular case. It is a simple design that is suitable for the systems and can be fixed in case of brokenness. This jaw coupling is made from cast iron.

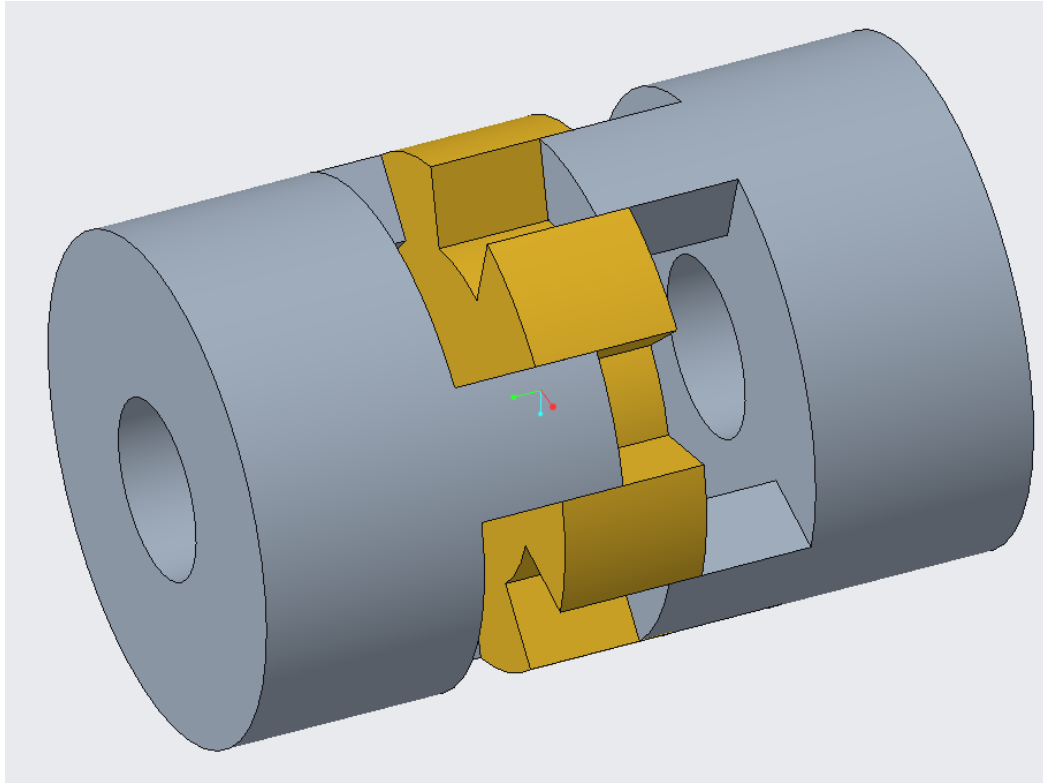


Figure 14. Coupling design

Another important component for this connection is the two shaft bearings that hold the rods together with the frame. It also adds more stability to the whole system.

The table below shows the specification of the jaw coupling:

Specification	Value	Units
Outer diameter	45	mm
Inner diameter	16	mm
Length	53	mm
Weight	0.007	kg

Table 4. Specification of the coupling

2.3.3.3/ Shaft bearing



Figure 15. Shaft bearing using in the project

For this system, two shaft bearings with inner rings diameter of 35 millimeter. The specification of this shaft bearing are:

Attribute	Value
Inside Diameter	35mm
Bearing Unit Type	Pillow Block
Material	Cast Iron
Centre Height	47.6mm
Mount Hole Size	17 mm
Length	167mm
Depth	42.9mm
Overall Height	93mm
Mount Hole Centre-to-Centre	127mm

Figure 16. Specification of Shaft bearing

These two shaft bearings are located on the two aluminum bars of the frame. There are four bolts to fix these two bearings on the bars. Its function for this system is:

- Holding the connecting rod of the systems.

- Supporting the torque transmission.

2.3.3.4/ Motor holder and servo motor

The last component to stabilize the gear motor to the frame is a motor holder. This holder is made from steel, its weight around 4 kilograms. Due to the nature of steel, it has enough strength to hold the gear motor and does not let the motor vibrate while it is operating.

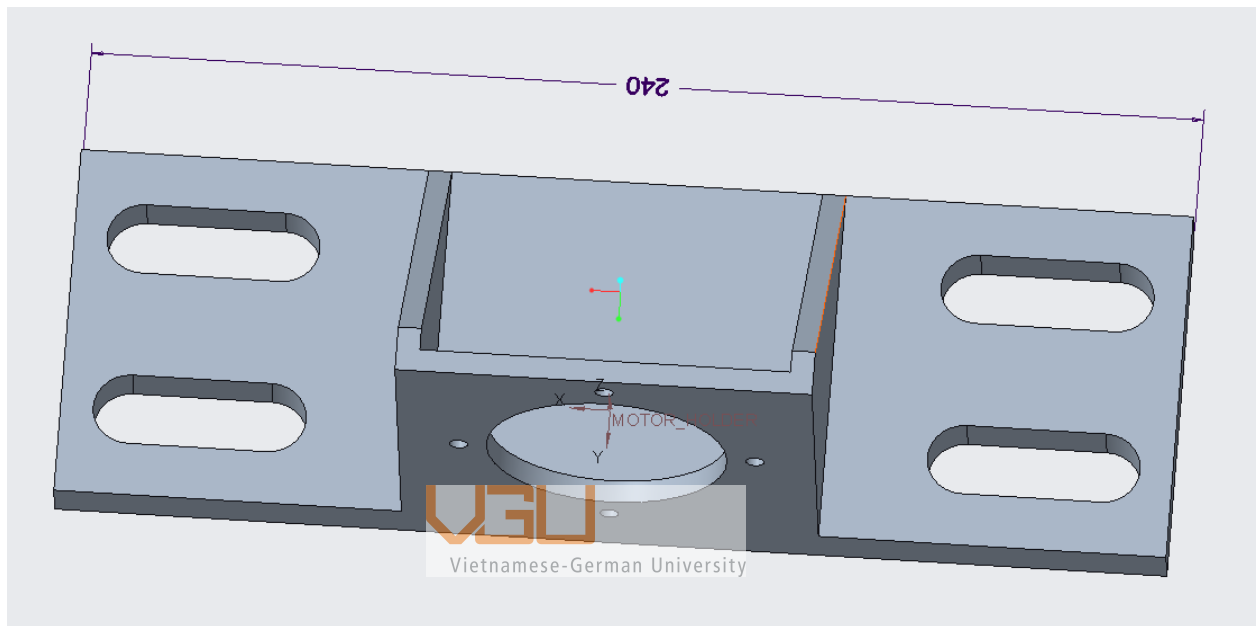


Figure 17. Design of the motor holder

On the motor holder, there are 4 holes aligned with 4 threads on the motor for further reinforcement of the stability of the motor when it is working. The reasons that this system need a motor holder are:

- Keeping the motor as the center of the rewind and unwind systems.
- Minimize vibration from the motor.
- Acting as the counter-balanced weight for the roller.

This holder is created by using a laser cutting machine. The raw material for this motor holder is 5mm thick steel, after having it cut from a big panel to the correct size according to the design of this holder, it is welded together. The table below shows specification of this motor holder:

Specification	Value	Units
Lengths	240	mm
Height	80	mm
Width	80	mm
Weight	5	kg
Volume	$0.625 \cdot 10^{-3}$	m^3

Table 5. Specification of the motor holder

The figure below shows the design of the motor which is held by the motor holder:

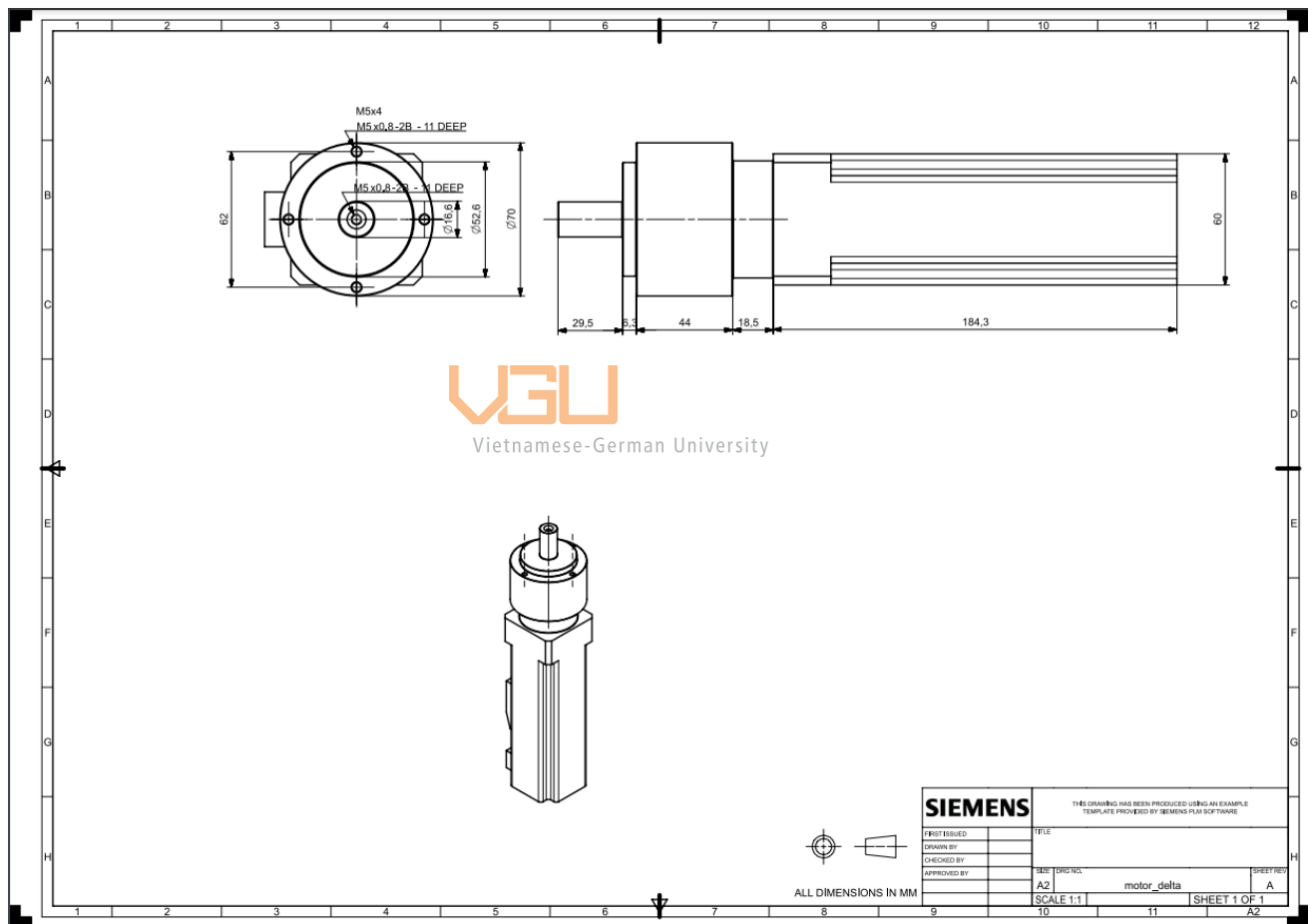


Figure 18. Design of the motor

2.3.4/ Connecting rewind and unwind systems with other systems of printing system

After the rewind and unwind systems have been assembled together, they will be connected with the rest of the web printing system by using L-shaped aluminum pieces as a connecting point. There are four bolts to stabilize the connection together.

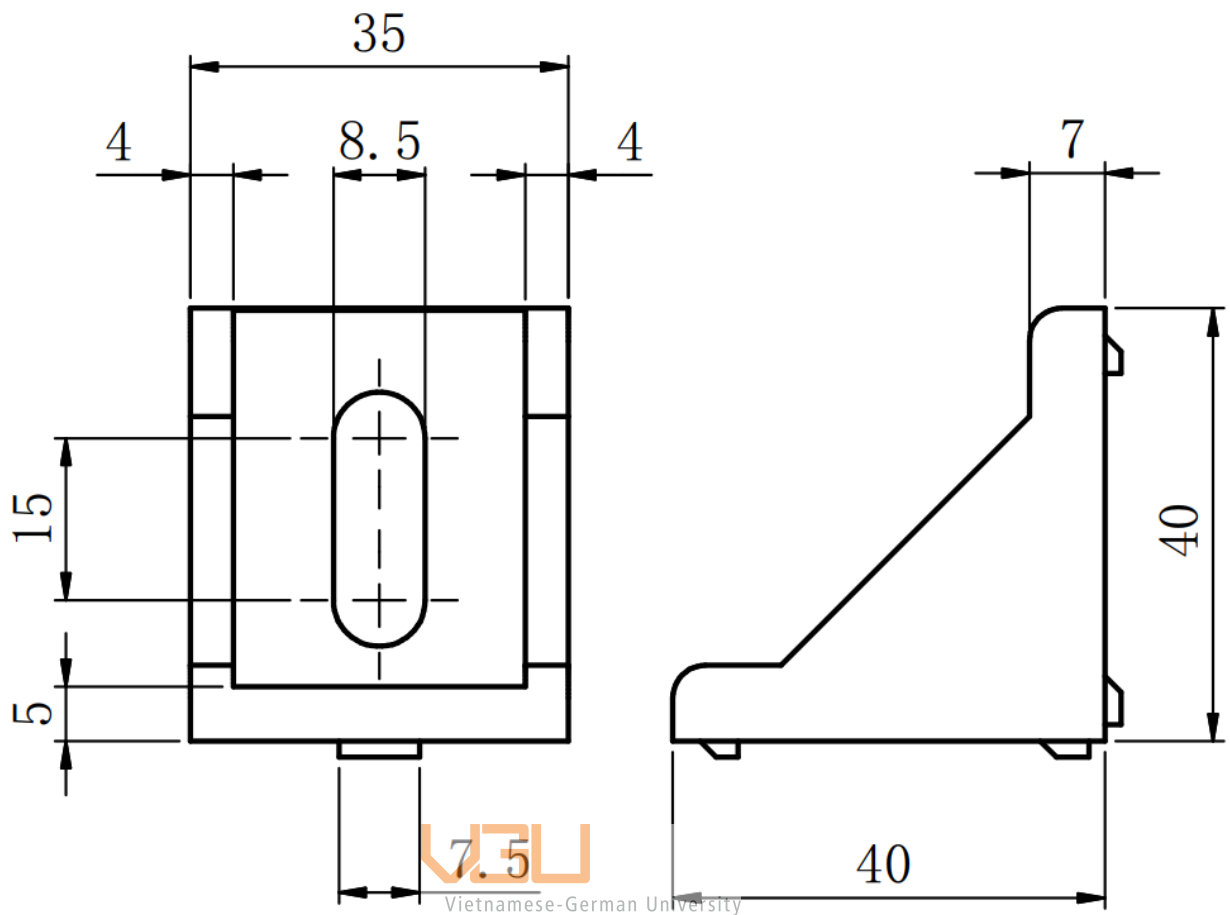


Figure 19. Design of tabbed bracket

The whole system can be removed as it is a modular design. The benefit of this design is that it can be transported and set up at another location. For this purpose, all modules of the web printing machine, including the rewind and unwind systems, have 4 wheels installed to them. These wheels are screwed to the frame of the systems.

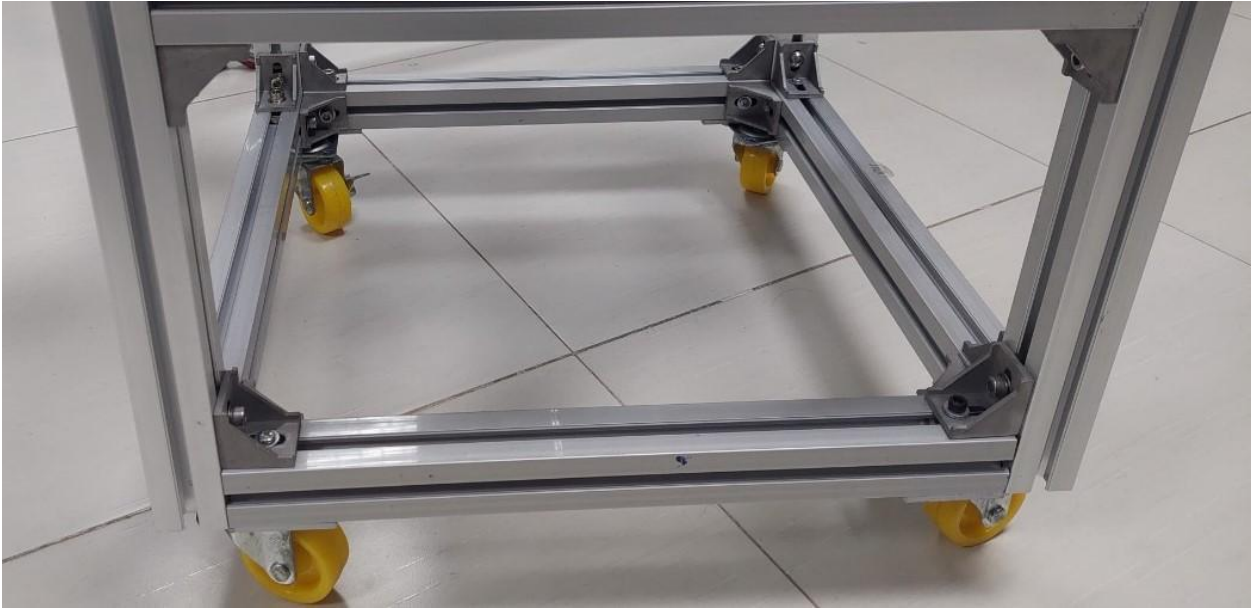


Figure 20. Rewind and unwind system with wheels screwed

2.3/ Mechanical Assembly

After having all the components making processes, the frame of the system is assembled first since it is the foundation of the whole system. Next step of the assembly process is to screw the motor holder and the first shaft bearing into the frame. An essential detail of this process is to align the virtual center line of the motor holder and the shaft bearing.

When the frame of the rewind and unwind systems is assembled, 4 wheels are screwed to the bottom of the frame.

Another sub-assembly process is to attach the coupling to the servo motor shaft. This process is done by screwing the first half of the coupling to the motor shaft, which has a hole on the shaft to stabilize the coupling. The other half of the coupling will be assembled to the connecting rod.

When the sub-assembly process is done, the servo motor would be attached and screwed to the motor holder. On the motor holder, there are 4 holes that were drilled to screw the bolt to the motor and stabilize the system. The figure below shows the servo motor after it had been screwed to the motor holder.

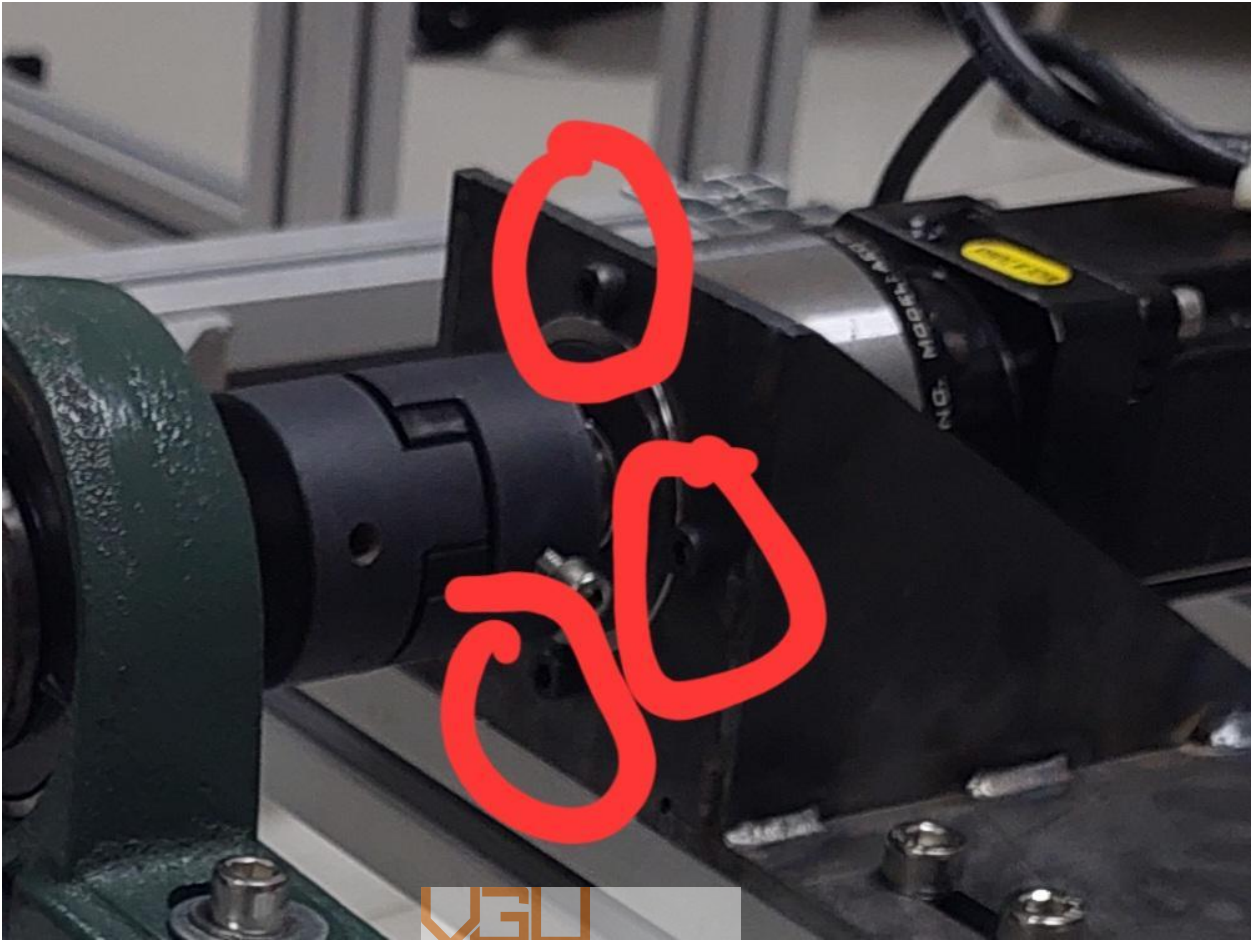


Figure 21. Servo motor connects to the motor holder

The second half of the coupling is attached to the connecting rod. First, it is connected to the first half of the coupling and the motor. After that, the connecting rod is connected to the coupling through the first bearing shaft that has been assembled to the frame earlier and fixed its position by screwing the bolt on the bearing to the connecting rod.

Next, the second shaft bearing is mounted on the frame, while also connecting it to the connecting rod. This shaft bearing is not fixed to the frame yet. It is moved further away from the final end of the connecting rod for another purpose with the roller.

When the second shaft bearing had been fixed on the frame, the roller is the last component needed to be assembled. There is a hole on the roller with the same diameter as the smaller part of the connecting rod. When the roller has connected to the connecting rod, a pin is pierced through both the roller and the connecting rod. The purpose of this pin is to stabilize the connecting rod and the

roller, it also makes sure that the turning force from the motor is transmitted to the roller for the system to be functional.

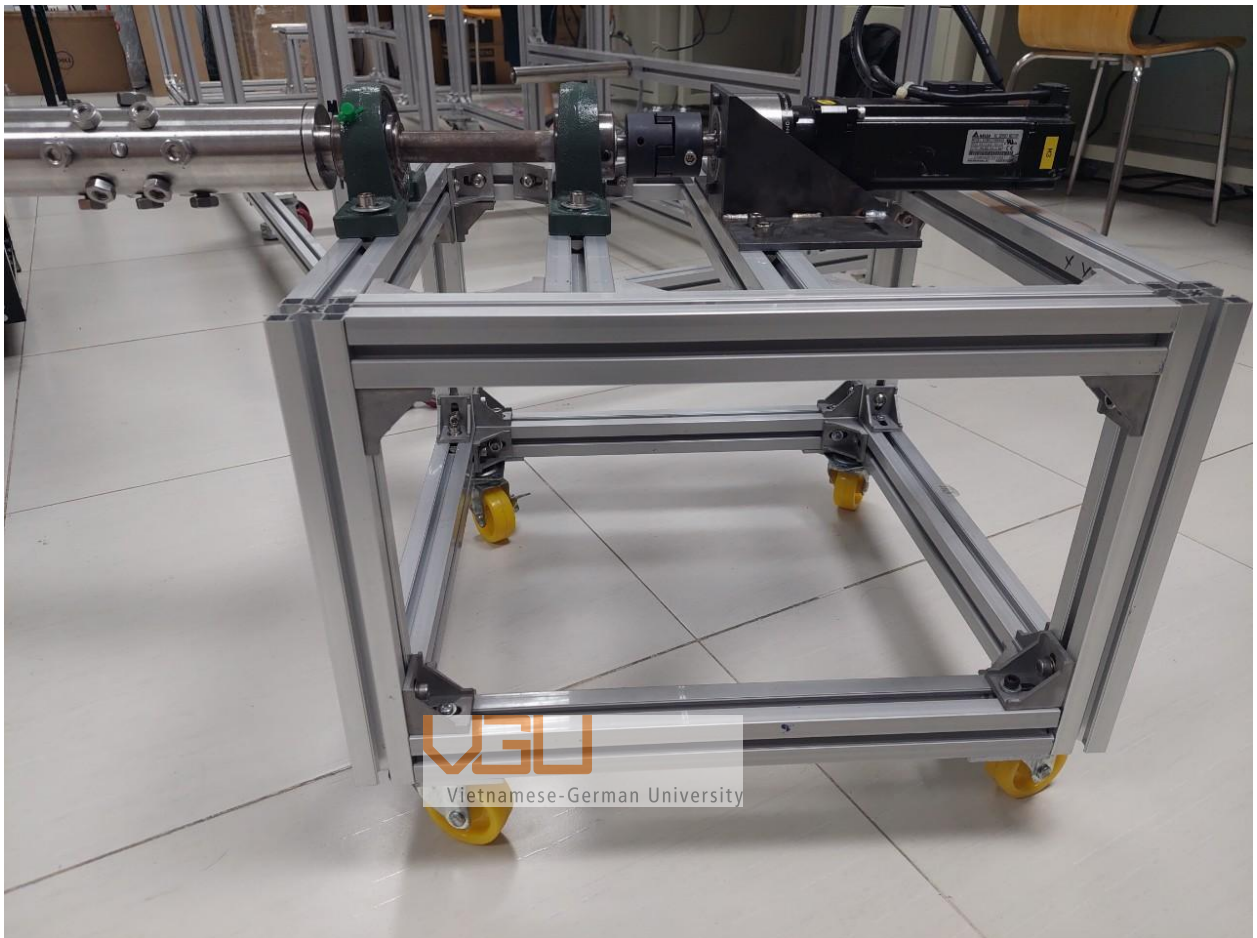


Figure 22. The rewind and unwind system after it has been assembled

When the rewind and unwind systems have been assembled, it is connected to the rest of the web printing machine and prepared for the test run of the web printing machine prototype.

The figures below show the other parts of the machine that will work together with the rewind and unwind systems and the whole prototype of the web printing machine.

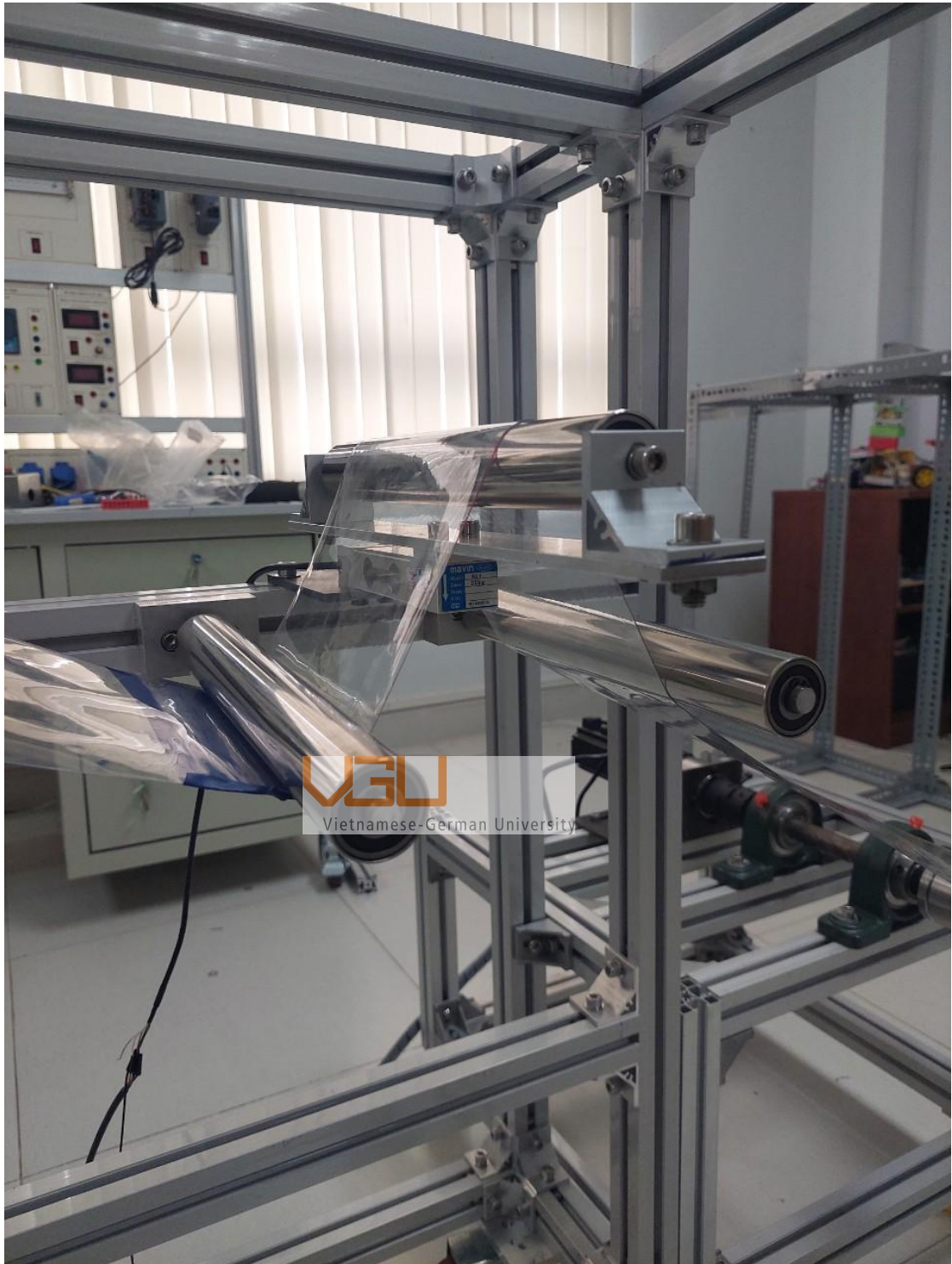


Figure 23. The force measurement system

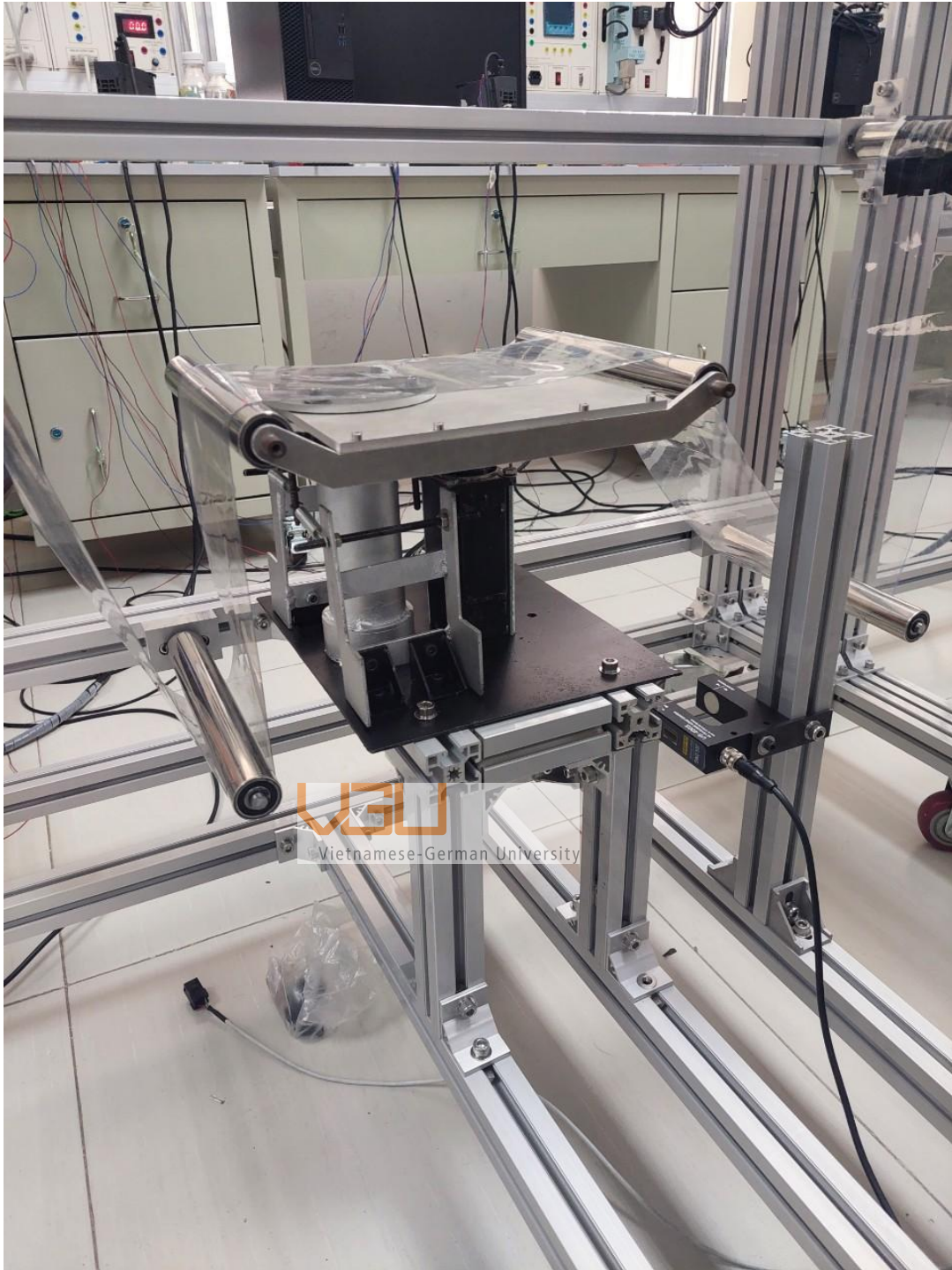


Figure 24. The align system to change to direction of the material roll

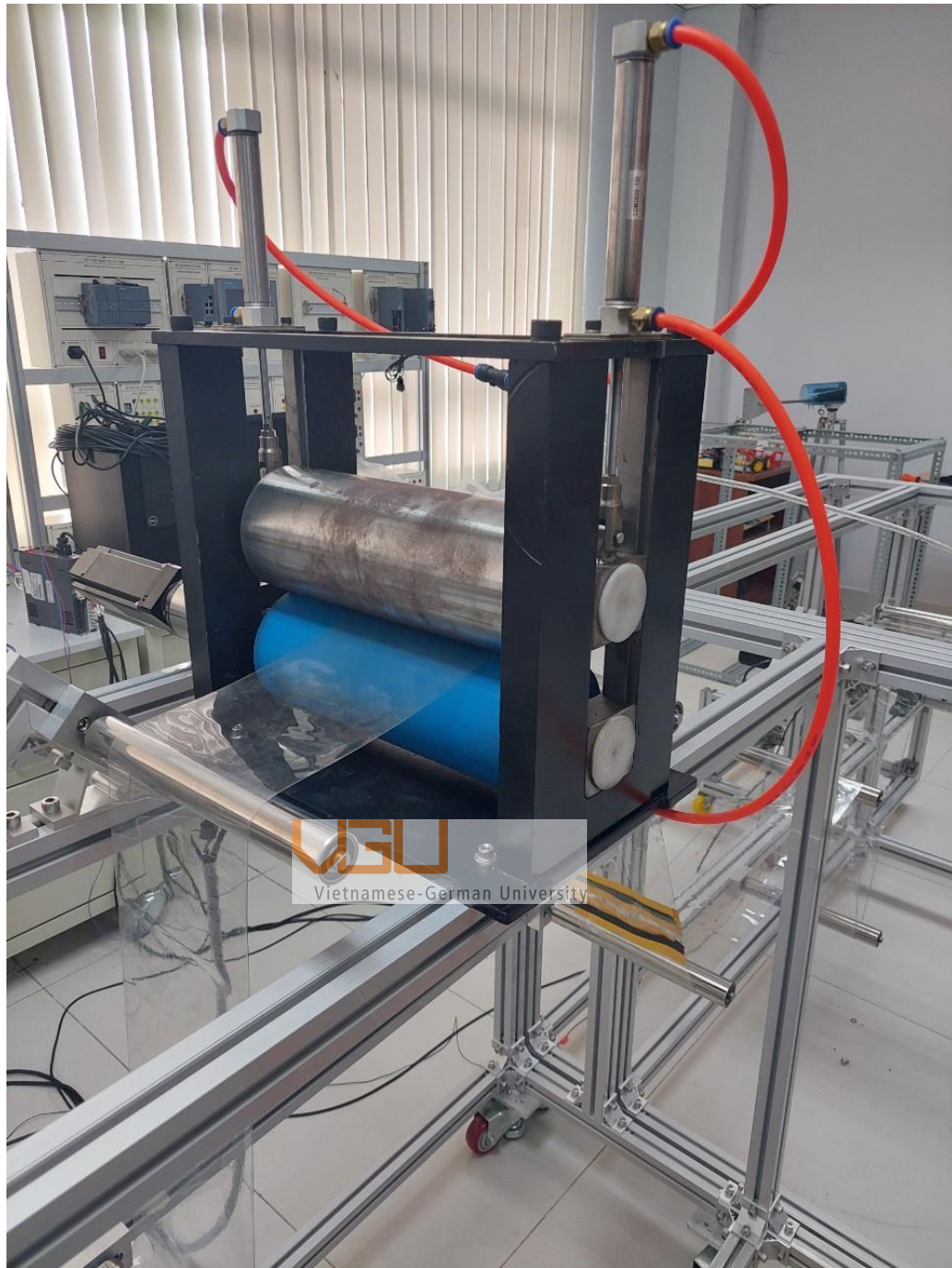


Figure 25. The nip roll system

Apart from the systems above, there are several other rollers that allow the material to travel from the unwind to the rewind system.



Figure 26. The prototype of the web printing machine

2.4/ Connecting with Electrical system

After the mechanical system has been assembled completely, the last step of assembling the web printing machine is to connect it with the electrical system. The electrical system has been prepared beforehand and simulation has been done to confirm there is no error while controlling the mechanical system.

The criteria for what motor should be chosen is power and the suitable properties for this project. There are 7 type of motor which can be used, they are AC Brushless Motors, DC Brushless Motors, DC Brushless Motors, Direct Drive, Linear Motors, Servo Motors and Stepper Motors.

In this case, a servo motor is chosen for not only the rewind and unwind systems but also for the nip roll system of the web printing machine. The specification of the servo motor for this project is:

Product Name	Electrical Commutation Motor
Driving type	AC Servo Motor
Rated Input Power	400W
Rated Voltage/ Rated Speed	220V/ 3000 rpm (used for low inertia)
Encoder type	Incremental encoder, 20-bit
Motor Frame Size	60 mm
Keyway (with screw hole)	Yes
With Brake	Yes
With Oil Seal	No
Standard Shaft Diameter	Yes

Table 6. AC servo motor specification



Figure 27. Servo motor

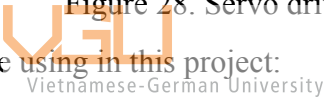
In charge of sending electric input information from the user to the servo motor is the servo drive. When the servo drive receives a signal from the program, it can decide to change the operation in

order to achieve the high accuracy according to the users' demand. After users send a signal to the servo drive, it will change the current frequency that can affect the output torque of the servo motor. The signal move between the servo drive and the controller will lower the error of the system and will achieve the torque demanded by the controller.



Figure 28. Servo drive

The specification of the servo drive using in this project:



Product Name	AC Servo Drive
Series	A2
Rated Output Power	400 W
Input Voltage and Phase	220V 1-phase/ 3-phase
Model Type	Standard Model including Extension Port for Digital Input (CN7), Ether CAT, CAN pen, DMCNET, E-CAM

Table 7. Specification of servo drive

In responsibility for controlling all of this is the PLC systems, including PLC and Personal computer for programming the programs. Using PLC will gain some advantages such as monitoring the feedback from the web printing machine and changing in torque or current of the machine so that users can find the optimal setting for the operation process. In short, PLC is the center of operation of this machine.



Figure 29. PLC

Other than these 3 components, There are HMI (Human - Machine Interface) for users to input their order for the machine, 220 VAC (Volt of Alternative current) power supply for supplying power for the servo drive, and a computer for creating a program for the PLC.



Figure 30. Human - Machine Interface (HMI)



Figure 31. Personal computer

CHAPTER 3: Experiments

3.1/ Stress test results

After the rewind and unwind systems have finished assembly, The next step of this project is to test if the system works with and without the material roll. The system is connected to the electrical system of the printing machine, which includes the servo drive, PLC, power supply and HMI system. The criteria of the testing is that the rewind and unwind systems are:

- The systems run perfectly with the material roll.
- No broken parts during the test runs.
- The system can handle up to 30 Nm of torque produced by the motor.

After 10 test runs, the torque produced by the motor increased from 5 Nm to the target of this project, which is 30 Nm, the rewind and unwind systems performed normally without any deformation or brokenness. When the torque reached 30 Nm, the machine was tested a couple more times to check if it would be broken with the material rolls installed.

When we finished testing the web printing machine without the material rolls, the next step was to repeat the test, this time with the material rolls installed. Currently, instead of using the printing material, the substitute material for testing the web printing machine is a PVC web with dimensions of 2 meters length and 20 centimeters width. The results this time is still satisfactory to the requirements of the project.

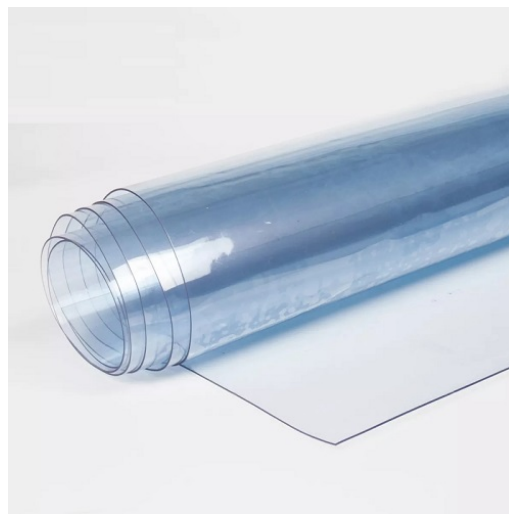


Figure 32. PVC web

3.2/ Results and discussions

After all the tests have been done, the rewind and unwind system are working stable, there are no defects or broken components found during the working time of the web printing machine.

The rewind and unwind system are able to handle the turning torque of 30 Nm. The result meets the goal of this project at the start. The connecting rod transmits most of the torque from the servo motor to the roller without a stability problem and the vibration from the servo motor is minimized with the system of motor holder and the shaft bearing.

However, the rewind and unwind system can be improved further, by changing the frame to a better material for more stable performance. Other than that, with a better shaft bearing installed, there would be less waste force and the performance of the system will be increased significantly.

Due to the material used to test the system, the roll is not stable and often drops from the roller. This problem can be solved by using an optimal material for printing instead of dropping constantly.

CHAPTER 4: Conclusion and future plan

4.1/ Conclusion

The main goal of this project is to create a prototype for the rewind and unwind system of the printing machine. The requirement for this project are:

- Design the mechanical parts of the rewind and unwind system.
- Making the prototype according to the design.
- Assembly the rewind and unwind system with the rest of the web printing machine.
- Test run if there is any problem affects the operation overall of the web printing machine.

Due to the requirement of the project, it is necessary to calculate all the components and change the design according to that calculation. In this case, the bending parameter of the roller, which is the most important parameter for the stability and longevity of the rewind and unwind system. After having all the numbers calculated, the material for the project can be chosen. The aim of the material choice are:



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- Keeping the balance of the system.
- Can be maintained easily.
- Easy to remove the roller.

After having all components assembled, the rewind and unwind systems are connected to the web printing machine and begin to test the operation of the machine. The desired torque of the web printing machine is 30 Nm. The rewind and unwind system can operate under this pressure and keep the system stable. However, the material can not hold to the roller for too long since it is not the optimal set up. In conclusion, the goal of this project is achieved, it is a workable prototype and it is a foundation for what could be developed later. Currently, this system can be used as a teaching tool for students to practice on PLC programming, which is an important part of Engineering design and automation Major, together with other systems of the web printing machine.

4.2/ Future plan


Even though the rewind and unwind systems are operating normally, some modification can be applied on this system for a better result.

Another frame can improve the stability of the system even more, and can use it for another purpose, such as storing the backup material roll. With another roller, which can be changed the diameter according to the size of the material rolls, it is possible to hold different rolls of material with different inner diameter of the center. Shaft bearings contribute to the overall torque transmission of the rewind and unwind systems, and with a better version of the same kind of shaft bearing that are used right now, the waste energy can be reduced.

One essential component of the rewind and unwind systems is the frame. Currently, it is made of aluminum alloy. Even though aluminum alloy is a great material due to its properties, another material can be used for better stability and durability.

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