

TECHNICAL INSTITUTE  
.....MECHANICAL ENGINEERING..... BACHELOR-  
.....Informatics specialisation

THESIS  
worksheet

Ibrahim Abuhasanein

for

Title of the diploma thesis: Design of a Hobby CNC Machine

Given laboratory process ....

Task reference:

...My thesis aims to design a 3 axis Hobby CNC Machine in Fusion360 which is a simple CNC machine, and Describing the material and the components that require to build it and to calculate the approximate cost of the machine for who wants to build a CNC machine.....

.....

Contributing department: Materials Science and Engineering Processes

Outsider consultant:

Insider consultant: Dr. Keresztes Róbert Zsolt associate professor, MATE Institute of Technology

Deadline of thesis submission: ....2024. year.....11.....month.....05...day

Date: Gödöllő, .....2024.....year .....11.....month .....01...day

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(student)

As the external consultant to the thesis writer, I declare that the student has attended the pre-arranged consultations.

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# Design of a Hobby CNC Machine

Name/ Ibrahim Abuhasanein

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## **1. Introduction**

Welcome, everyone! Today, we're diving into one of the most accessible and versatile types of CNC machines: the CNC router. We'll explore how it works and why.

Computer Numerical Control (CNC) machines have revolutionized the manufacturing landscape by introducing unprecedented levels of precision, efficiency, and flexibility in machining processes. Originating in the late 1940s with the development of numerical control (NC) machines, CNC technology has undergone significant advancements over the decades, driven by the evolution of computer technology and software. From early systems that relied on punched tape to modern machines integrated with artificial intelligence and internet of Things (IoT) capabilities, CNC machines have become indispensable tools in industries such as metalworking, woodworking, and plastics fabrication.

My thesis explores the historical development, operational principles, types, and applications of CNC machines, providing a comprehensive overview of their transformative impact on manufacturing. It highlights the progression from the initial use of simple NC machines to the sophisticated CNC systems of today, emphasizing the role of software in facilitating complex designs and automating production. Furthermore, the study delves into current trends, including the integration of advanced technologies and sustainability initiatives, and examines the future trajectory of CNC machining in the context of industry.

By understanding the evolution and functionality of CNC machines, this research aims to shed light on their critical role in modern manufacturing, illustrating how these technologies not only enhance productivity but also drive innovation and customization in an increasingly competitive market.

## **2. Liteture Review about CNC Machine:**



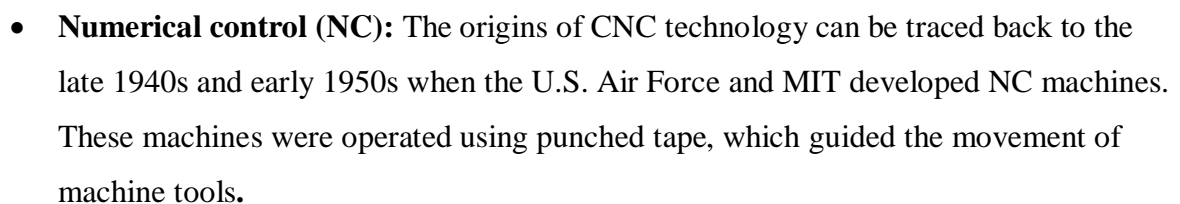


**Figure 1 : CNC machine**

Figure 1: Possibilities of preparing diagrams(Source: own editing based on KSH (2005, 2010))

CNC (Computer Numerical Control) machines are advanced manufacturing tools that automate the control of machining tools through computer programming. They are widely used in various industries for precision machining, including metalworking, woodworking, and plastic fabrication.

## Early Beginnings (1940s-1950s)



### **Development of CNC technology (1960s)**

- **Introduction of Computers:** In the 1960s, as computers became more accessible, the first CNC machines emerged. These machines used computer programs to control their movements instead of punched tape, greatly increasing flexibility and precision.

### **Advancements in Software (1970s)**

- **G-Code and Programming:** The development of G-code (Geometric Code), a language that describes movements and actions for CNC machines, occurred in this decade. This standardization allowed for more complex machining operations.

### **Expansion and Popularization (1980s)**

- **Personal Computers and Accessibility:** The introduction of personal computers in the 1980s made CNC technology more accessible to smaller manufacturers. This led to an explosion of CNC machine production and use across various industries.

### **Industry Standardization (1990s)**

- **Improved accuracy and speed:** CNC machines became more sophisticated, with enhancements in speed and accuracy. The integration of CAD/CAM software allowed for better design and manufacturing processes.

### **Modern Advancements (2000s-Present)**

- **Integration with Other Technologies:** The 2000s saw the incorporation of advanced technologies such as robotics, automation, and IoT connectivity, allowing for more streamlined and efficient manufacturing processes.
- **Additive Manufacturing:** The rise of 3D printing and hybrid machines that combine additive and subtractive manufacturing capabilities further expanded the capabilities of CNC technology.



## Conclusion

The history of CNC machines reflects significant technological advancements that have transformed manufacturing. From the early days of punched tape to today's sophisticated, computer-driven machines, CNC technology has continually evolved to meet the demands of various industries. As we move forward, the integration of AI, IoT, and other emerging technologies promises to shape the future of CNC machining even further.

([History of CNC Technology – EngineeringTechnology.org](https://www.EngineeringTechnology.org))

### 2.2 How does a CNC machine works?



**Figure 3 :** Laser cutting CNC machine

Part of what makes CNC machining different is the use of computer programming. Before cutting, Users input steps into a software program, and the tools connected to the CNC machine carry out these commands to achieve the desired outcome.

While this process may seem robotic, CNC programming ensures you still have control over the design. Modern software has made it much easier to craft complex parts because you can outline pieces virtually, suggesting tool paths for making the parts. This can also help minimize flaws.

CNC machining uses two types of software, including:

- **Computer-Aided drawing (CAD):** Most CNC projects begin with CAD software, which helps users with the design process. Some programs strictly offer CAD drawing, while others feature some CAM (computer-aided manufacturing) skills or may be integrated more smoothly with CAM software.
- **Computer-Aided Manufacturing (CAM):** Cam software helps make the entire manufacturing process more efficient. This software allows the programmer to set paths for tools and run simulations to see how cuts may look in reality. They even help them keep their work more organized. Many Cam programs serve as add-ons to computer-aided design, generating G-code that instructs tools how to move. G-code is the most common programming language for CNC machines.

From cabinet making and automotive to aerospace and guitars, CNC machines can be employed for almost any use. Additionally, as they're compatible with many materials, they're helpful for woodworking and metalworking alike. Industries utilizing CNC machining include:

- Art (33%)
- Prototyping (25%)
- Cabinetry & Furniture (17%)
- Machine Parts (17%)
- Signage (8%)



**Figure 4 : Guitars made by CNC Routers**

[\(How Do CNC Machines Work? - Marshall Manufacturing - Medical Device Manufacturing\)](#)

### 2.3 Types of CNC machine:

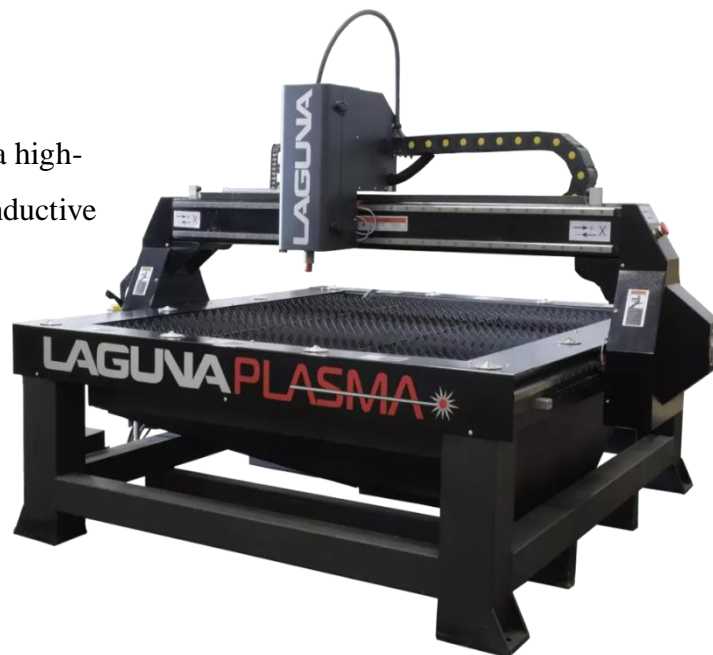
CNC machines come in various types, each designed for specific applications. Here are some common types:

1. **CNC Milling Machines:** These machines use rotary cutters to remove material from a workpiece. They can perform various operations, including drilling, boring, and slotting.
2. **CNC Lathes:** These machines rotate the workpiece against a stationary cutting tool, ideal for creating cylindrical parts, such as shafts and fitting.
3. **CNC Router:** Typically used for cutting softer materials like wood, plastic, and composites, CNC routers are commonly found in woodworking and sign-making industries.



**Figure 5: CNC Router**

4. **CNC Plasma Cutters:** These machines use a high-velocity jet of ionized gas to cut through conductive materials like steel and aluminium.



**Figure 6 : CNC Plasma Cutters**

5. **CNC Waterjet Cutters:** Utilizing a high-pressure stream of water mixed with abrasives, these machines can cut through a wide range of materials, including metal, glass, and stone.
6. **CNC EDM (Electrical Discharge Machining):** This type uses electrical discharges to erode material, suitable for intricate shapes and hard materials, often used for mold making.
7. **CNC Laser Cutters:** Using focused laser beams, these machines cut or engrave materials with high precision. They are widely used in metal fabrication and design.
8. **CNC 3D Printers:** While not traditional CNC machines, 3D printers use CNC technology to create three-dimensional objects layer by layer.
9. **CNC Hybrid Machines:** These combine multiple functions, such as milling and additive manufacturing, allowing for versatile production capabilities.
10. **CNC Turn-Mill Centers:** These machines combine lathe and milling capabilities in a single setup, ideal for complex parts that require both turning and milling operations.

Each type of CNC machine is tailored to specific materials and applications, making them invaluable in various manufacturing processes.

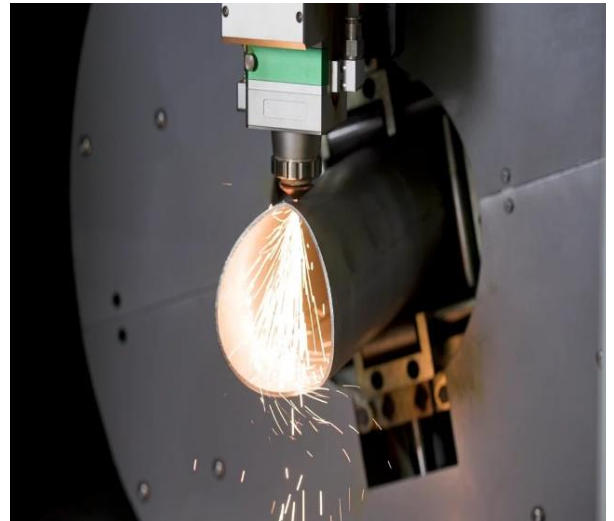
[\(15 Types of CNC Machines Commonly Used in Manufacturing | Machinery Network\)](#)

## **2.4 Tools used with CNC machines:**

Another benefit of CNC machines is the ability to pair with different tools and find new applications. To expand your uses of CNC machining, discover some of the most common components incorporated into CNC systems:

- Laser cutters
- Wood Routers
- 3D Printers
- Glass Cutters
- Foam Cutters
- Embroidery Machines
- Cylindrical Grinders
- Turret Punchers
- Wire-Bending Machines

[\(15 Main Types of CNC Machines Explained - CNCsourced\)](#)



**Figure 7 :** Laser cutter

## 2.5 Key Features of CNC machines:

1. **Precision and Accuracy:** CNC machines can produce parts with a high degree of accuracy, often within thousandths of an inch. This precision is essential in industries like aerospace and automotive, where even minor errors can lead to significant issues.
2. **Automation:** CNC machines operate automatically based on programmed instructions. Once a design is input, the machine can run with minimal human intervention, increasing efficiency and reducing the risk of human error.
3. **Versatility:** CNC machines can handle various operations such as milling, turning, drilling, and laser cutting. This versatility allows manufacturers to create complex shapes and designs.
4. **Repeatability:** CNC machines can produce the same part repeatedly with consistent quality, making them ideal for high-volume production runs.
5. **Complex Geometry:** With the ability to interpret complex CAD (Computer-Aided Design) files, CNC machines can create intricate designs that would be challenging to achieve with manual machining.

## 2.6 Applications:

- **Manufacturing:** Used for producing components in automotive, aerospace, and electronics industries.
- **Prototyping:** Ideal for creating prototypes and one-off pieces in product development.
- **Custom Fabrication:** Used in woodworking and metalworking for custom projects.



## [\(Top Features of CNC Machines Explained\)](#)

### **2.7 Conclusion:**

CNC technology has revolutionized manufacturing by enhancing precision, efficiency, and the ability to create complex designs. As technology continues to advance, CNC machines are becoming more integrated with automation and smart manufacturing processes, further shaping the future of production.

### **2.8 Trends in CNC Technology: AI Integration and Beyond:**

The landscape of CNC technology is rapidly evolving, driven by advancements in artificial intelligence (AI), automation, and data analytics. These trends are revolutionizing manufacturing processes, improving efficiency, and enhancing product quality. Here's a detailed look at some of the key trends in CNC technology:

#### **1. AI and Machine Learning Integration:**

- **Predictive Maintenance:** AI algorithms analyze data from CNC machines to predict when maintenance is required. This proactive approach reduces downtime and extends machine lifespan.
- **Quality Control:** AI can monitor production in real-time, detecting anomalies and quality issues before they escalate. This leads to more consistent product quality and reduced waste.
- **Adaptive Machining:** Machine learning models can optimize machining parameters (e.g., speed, feed rates) based on material characteristics and environmental factors, enhancing overall machining performance.

#### **2. Internet of Things (IoT) Connectivity:**

- **Real-Time Monitoring:** IoT-enabled CNC machines can transmit data regarding their performance, status, and production metrics. This connectivity allows for centralized monitoring and control.
- **Smart Factory Ecosystems:** CNC machines are integral to smart factories, where interconnected devices work collaboratively to enhance operational efficiency and productivity.

#### **3. Advanced Automation:**

- **Collaborative Robots (Cobots):** Cobots work alongside CNC machines to perform repetitive tasks like loading and unloading, improving efficiency and reducing the risk of human error.
- **Automated Workflows:** Fully automated production lines reduce the need for manual labor and can operate continuously, significantly increasing throughput.

#### 4. Enhanced Software Solutions:

- **AI-Driven CAD/CAM:** New CAD/CAM software integrates AI to assist in design and machining processes, streamlining workflows and improving design efficiency.
- **Simulation and Virtual Testing:** Advanced simulation tools enable engineers to visualize machining processes and test designs in a virtual environment, reducing errors and optimizing setups before physical production.

#### 5. Integration of additive Manufacturing:

- **Hybrid Systems:** Some CNC machines now feature Hybrid Capabilities that combine traditional subtractive machining with additive manufacturing, allowing for complex geometries and material savings.
- **Material Flexibility:** The ability to work with various materials, including metals, plastics, and composites, is expanding the potential applications of CNC technology.

#### 6. Data Analytics and Big Data:

- **Performance Analytics:** Utilizing big data analytics, manufacturers can assess performance metrics, identify trends, and make data-driven decisions to optimize operations.
- **Root Cause Analysis:** Data analytics can help pinpoint the root causes of production issues, facilitating quicker resolutions and improving overall efficiency.

#### 7. Cybersecurity Measures:

- **Protecting Sensitive Data:** As CNC machines become more connected, cybersecurity is crucial. Manufacturers are investing in robust security protocols to protect sensitive data and ensure operational integrity.
- **Risk Management:** Implementing comprehensive risk management strategies helps safeguard against potential cyber threats that could disrupt manufacturing processes.

## 8. Sustainability Initiatives:

- **Energy-Efficient Machines:** The development of energy-efficient CNC machines helps reduce the carbon footprint of manufacturing operations.
- **Material Recycling:** Advanced CNC techniques focus on minimizing waste and enhancing material recycling, aligning with global sustainability goals.

[\(The Future of CNC: 7 Emerging Trends to Watch\)](#)

## Conclusion:

The integration of AI and other advanced technologies is shaping the future of CNC machining, making processes more efficient, flexible, and sustainable. As manufacturers adopt these trends, they will enhance their competitive edge in an increasingly dynamic market. Staying ahead of these developments is essential for businesses looking to thrive in the evolving landscape of manufacturing.

### 2.9 The Future of CNC in manufacturing:

The future of CNC (Computer Numerical Control) in manufacturing is poised to be transformative, driven by advancements in technology, increased automation, and evolving industry needs. Here are some key trends and developments shaping the future of CNC machining:

#### 1. Integration with Industry:

- **Smart Factories:** CNC machines are increasingly being integrated into smart factories where IoT (Internet of Things) devices collect data and communicate in real-time. This enhances productivity and allows for predictive maintenance.
- **Data Analytics:** Advanced data analytics can be used to monitor machine performance, optimize operations, and reduce downtime.

#### 2. Advanced Automation and Robotics:

- **Collaborative Robots (Cobots):** Cobots can work alongside CNC machines, helping to load and unload parts, increasing efficiency and safety.
- **Automated Workflows:** Fully automated CNC systems can operate around the clock, reducing the need for manual intervention.

#### 3. Additive Manufacturing Integration:

- **Hybrid Machines:** Some new CNC machines combine subtractive and additive manufacturing processes, allowing for more complex designs and reduced waste.
- **Material innovation:** The ability to work with a broader range of materials, including composites and advanced alloys, opens new avenues for product design.

#### 4. Increased Customization:

- **On-Demand Manufacturing:** CNC technology enables manufacturers to offer customized products more efficiently, meeting consumer demand for personalized solutions.
- **Shorter Production Runs:** Advanced CNC setups allow for smaller batch sizes without sacrificing efficiency, making it easier to adapt to market changes.

#### 5. Enhanced Software and Simulation Tools:

- **CAD/CAM Innovations:** Improved CAD/CAM software offers better design capabilities and more intuitive interfaces, streamlining the workflow from design to production.
- **Virtual Reality (VR) and Augmented Reality (AR):** These technologies can be used for training and simulation, allowing operators to visualize and interact with CNC processes before implementation.

#### 6. Sustainability and Eco-Friendly Practices:

- **Energy Efficiency:** New CNC machines are being designed for lower energy consumption, reducing the overall environmental impact of manufacturing.
- **Waste Reduction:** Advanced machining strategies minimize material waste, and recycling initiatives are becoming more common in CNC operations.

#### 7. Workforce Development:

- **Training Programs:** As CNC technology evolves, ongoing training programs will be essential for workers to keep pace with new technologies and methods.
- **Skill Diversification:** The future workforce will need a blend of traditional machining skills and advanced technological knowledge, including programming and data analysis.

[\(The Future of CNC: 7 Emerging Trends to Watch\)](#)

## **Conclusion:**

The future of CNC in manufacturing is bright, marked by innovation and adaptability. As technology continues to evolve, CNC machining will play a critical role in shaping the future of manufacturing, enabling businesses to remain competitive in an increasingly dynamic market. Embracing these trends will be essential for manufacturers looking to thrive in the coming years.

### **2.10 The most simple CNC machine: The CNC Router:**

One of the simplest and most accessible types of CNC machines is the CNC router. These machines are widely used for both hobbyist and small-scale production projects due to their straightforward design and versatility.

#### **2.11 How it works:**

##### **1. Basic Components:**

- **Frame:** Usually made of aluminum or steel, providing stability.
- **Stepper Motors:** Control the movement of the machine along the X, Y, and Z axes.
- **Controller:** A computer or microcontroller that interprets the design file and sends commands to the motors.
- **Cutting tool:** Typically a router bit that removes material from the workpiece.

##### **2. Operation:**

- **Design:** Users create a design using CAD software, which is then converted into G-code (the language CNC machines understand)
- **Setup:** The material is securely placed on the machine bed.
- **Execution:** Once everything is set, the machine follows the Gcode instructions, moving the cutting tool precisely along the programmed paths to carve out the desired shape.

### **2.12 Why use a simple CNC Router?**

1. **Affordability:** CNC routers can be more cost-effective than larger CNC machines, making them accessible to hobbyists and small businesses.



2. **Ease of Use:** Many entry-level CNC routers come with user-friendly software, allowing beginners to quickly learn and operate the machine.
3. **Versatility:** They can cut, carve, and engrave various materials, including wood, plastic, and soft metals, making them suitable for a wide range of projects from furniture making to sign creation.
4. **Space Efficiency:** Unlike larger CNC machines, CNC routers often have a smaller footprint, making them suitable for workshops with limited space.
5. **Creative Expression:** CNC routers enable users to explore intricate designs and patterns, facilitating creativity in crafting and fabrication.

## **Conclusion:**

The CNC router exemplifies how a simple CNC machine can empower users to bring their ideas to life with precision and efficiency. Its affordability and versatility make it a popular choice for both beginners and experienced makers, illustrating the democratization of advanced manufacturing technology.

### **2.13 CNC machine Letecture Summary:**

Computer Numerical Control (CNC) machines are advanced manufacturing tools that automate the machining process using computer systems. Unlike traditional machines, CNC machines are programmed with precise instructions, allowing for high levels of accuracy and repeatability in producing complex parts.

**Key Components:** CNC systems consist of a computer, control software, motors, and tooling. The process begins with a design created in CAD (Computer-Aided Design) software, which is then converted into G-code, a programming language that instructs the machine on how to move and operate.

**Types of CNC Machines:** There are several types of CNC machines, including milling machines, lathes, routers, and laser cutters. Each type serves different manufacturing needs from cutting and shaping materials to engraving and 3D printing.

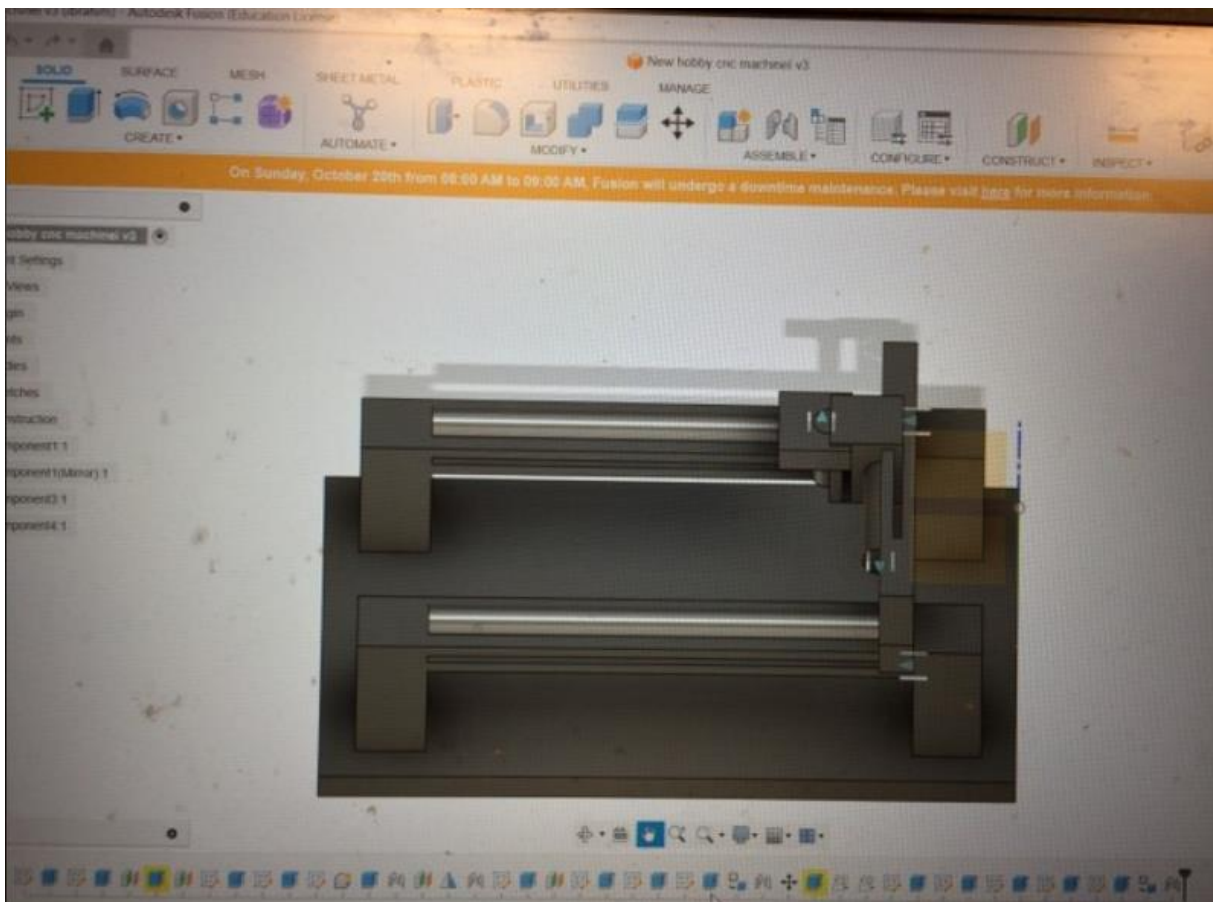
**Benefits:** CNC machines enhance productivity through automation, reduce human error, and enable the production of intricate designs that would be difficult or impossible to achieve

manually. They also allow for on-demand manufacturing, reducing material waste and inventory costs.

**Future Trends:** The integration of technologies like artificial intelligence (AI), IoT (Internet of Things), and data analytics is transforming CNC machining. These innovations enable predictive maintenance, real-time monitoring, and enhanced automation, further increasing efficiency and sustainability in manufacturing.

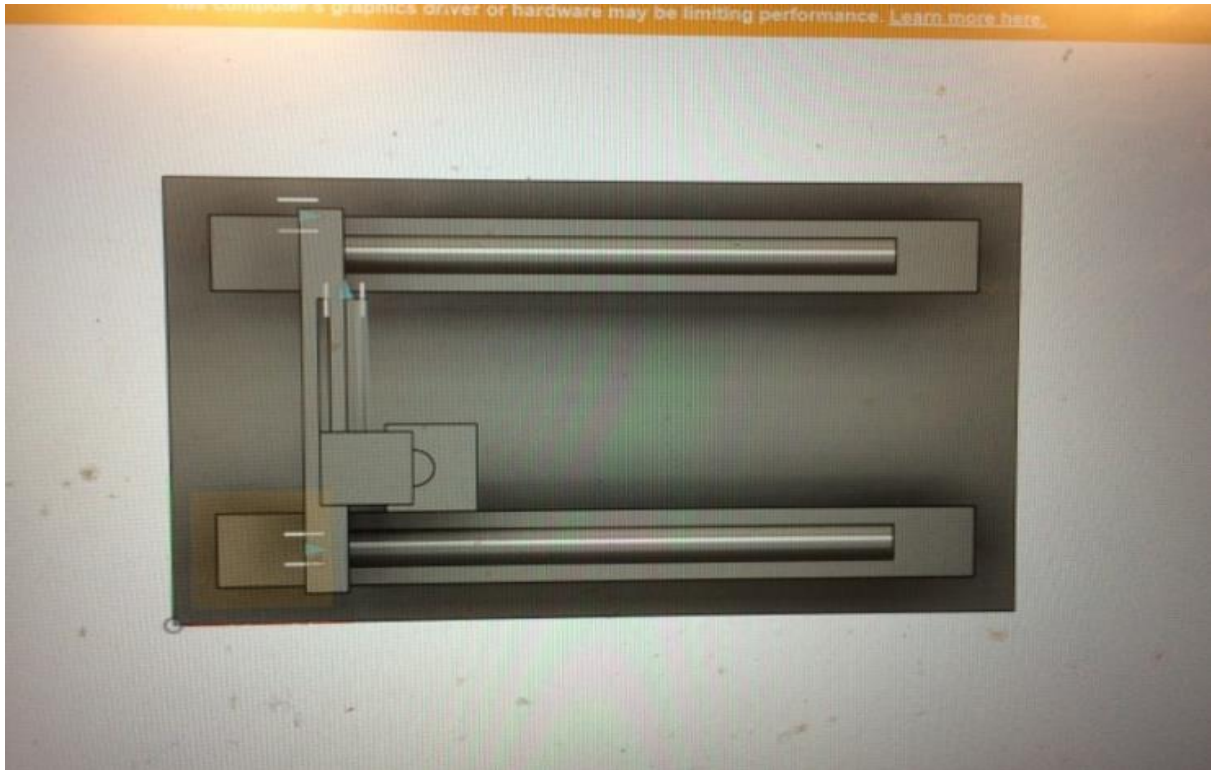
In conclusion, CNC machines represent a significant advancement in manufacturing technology, driving the industry toward greater precision, efficiency, and customization.

### 3. Design of a 3D Model for a simple 3-axis Hobby CNC machine:



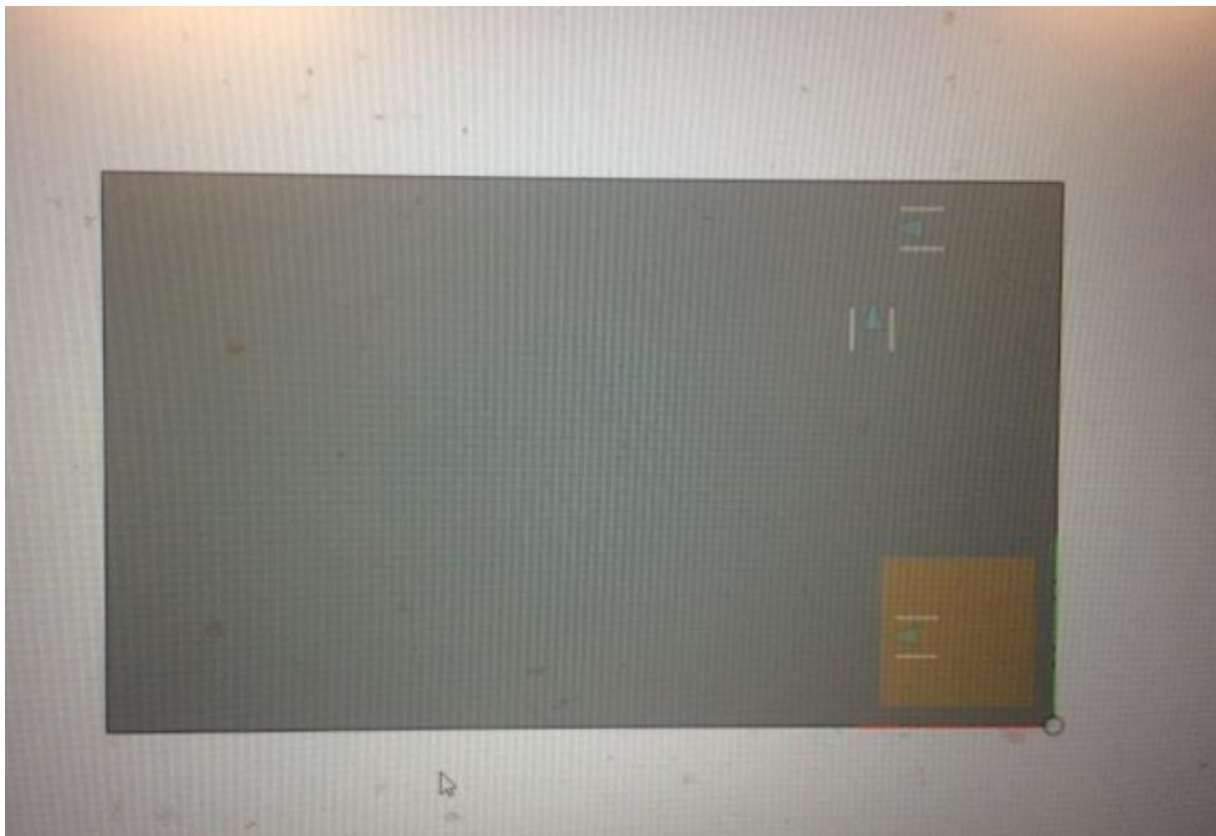
**Figure 8 :** My design of a 3D Model for a simple 3-axis Hobby CNC machine

Front view:



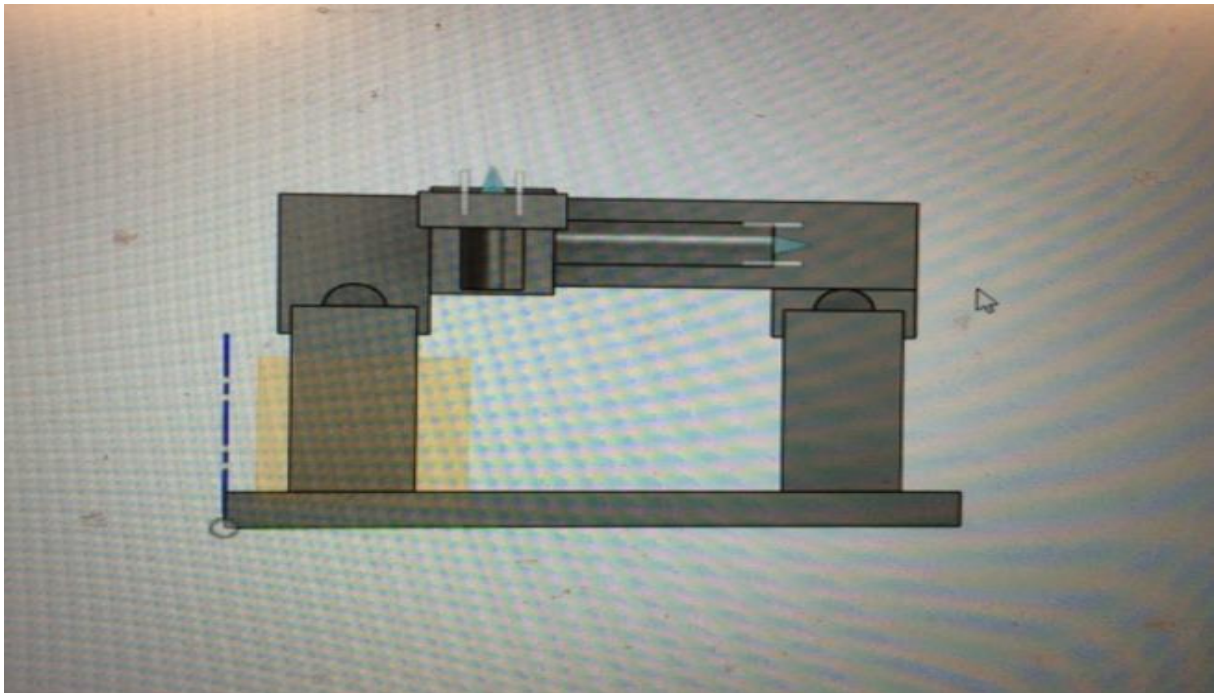
**Figure 9 : Front view**

Back view:



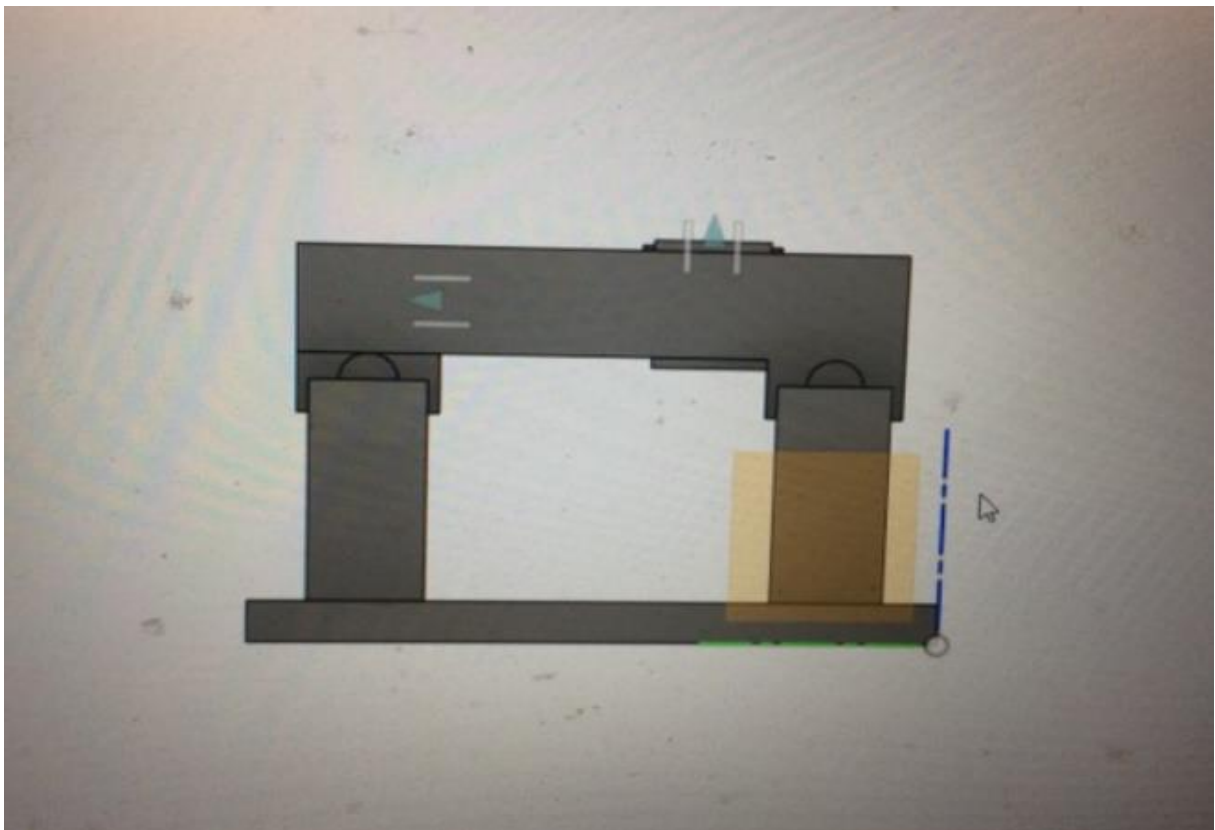
**Figure 10 : Back view**

Right view:



*Figure 11 : Right view*

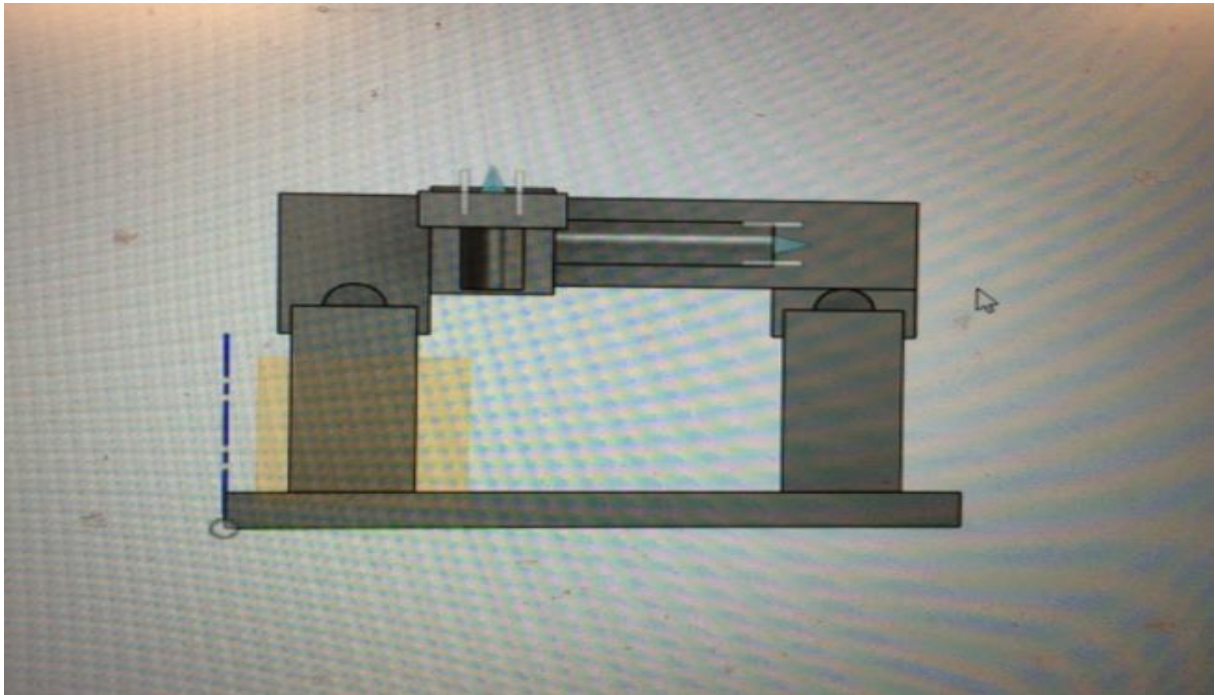
Left view:



**Figure 12 : Left view**

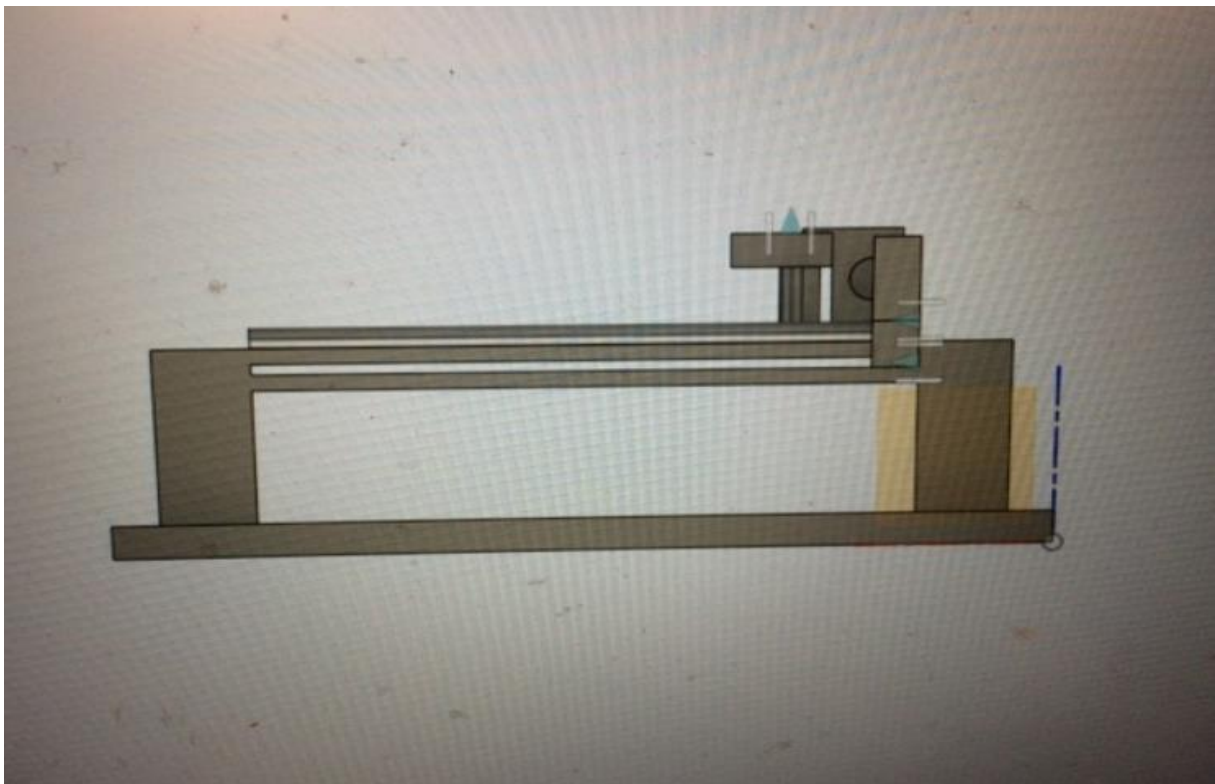


Top view:



**Figure 13 :** Top view

Bottom view:



**Figure 14 :** Bottom view



My work aims to design a 3D model for a simple 3-axis hobby CNC machine, aimed at facilitating easy fabrication. Utilizing Fusion 360, I created an initial 3D model that emphasizes ease of assembly, material fabrication, and cost-effectiveness.

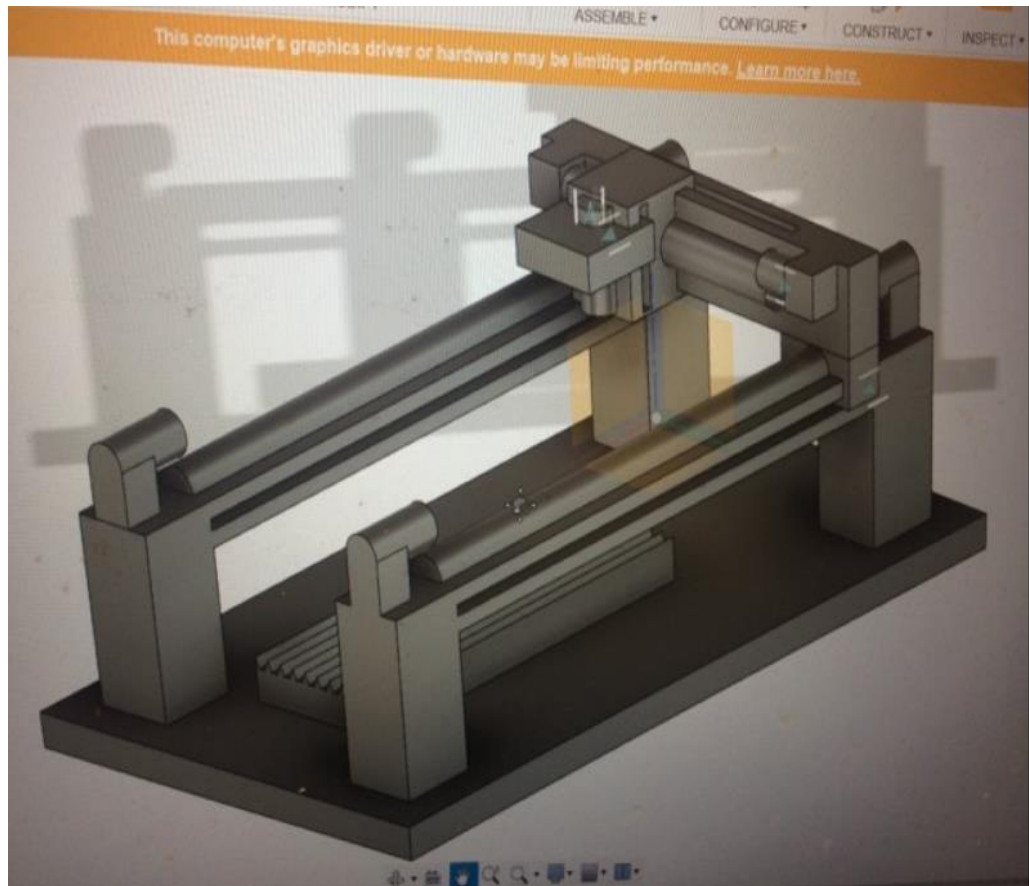
### 3.1 3D Model Development Process:

1. **Frame Creation:** A sketch was initiated in the XY view, establishing the frame dimensions at 300 mm by 500 mm. This sketch was subsequently extruded 20 mm along the Z- axis.
2. **Support Columns:** In the same XY view, a sketch for the top of the frame was developed, defining four support columns, each measuring 50 mm by 50 mm. These columns were then extruded 80 mm along the Z-axis.
3. **X-Axis Rails:** An offset plane was created in the YZ orientation at the face of the left side of the support columns. On this plane, two rectangles representing the X-axis rails were sketched, measuring 50 mm by 2 mm, and extruded 450 mm along the X-axis to reach the ends of the adjacent support columns.
4. **Circle Features on X-axis rails:** A second offset plane was established parallel to the YZ axis, positioned 73 mm from the original YZ axis. A sketch featuring two circles, each with a 25 mm diameter, was created at the center of the top edge of the X-axis rails. These circles were then extruded 350 mm along the X-axis.
5. **Joint support structure:** A sketch was drawn on the left side of the X-axis rails, featuring a rectangle with dimensions of 300 mm in the X direction and 6.25 mm in the Z direction. The rectangle's top edge was positioned 9.375 mm below the top edge of the X- axis rails. This sketch was then cut to a length of 250 mm to align with the end of the second X-axis rail, ensuring secure joint support.
6. **Joint Components for X-axis Movement:** A sketch was created for two joint components for the X-axis movement rails on the previously established 75 mm offset plane. The Y-axis dimensions for the joints was set at 60 mm, considering the 50 mm width of the X-axis rails.
7. **Slider Joint Assembly:** The two joints components were assembled into slider joints, and a motion link was created to ensure synchronized movement.
8. **Y-Axis Rail:** A sketch for Y-axis rails was developed on top of one of the joints, comprising a rectangle with dimensions of 25 mm by 25 mm. This

sketch was extruded 260 mm along the Y-axis , accounting for an additional 10 mm added for the joints.

- 9. Additional Offset Plane:** An offset plane was created in the XZ orientation, set 80 mm in the Y direction. A sketch on this plane featured a circle with a 25 mm diameter for the Y-axis movement rail, which was extruded 140 mm.
- 10. Y-Axis RailJoint Support:** A sketch on the top of the Y-axis rail included a rectangle measuring 6.25 mm by 140 mm. This sketch was cut to a depth of 50 mm along Z-axis direction, serving to secure the Y\*axis rail joint.
- 11. Y-axis Joint Component:** A sketch for one component of the Y-axis movement rail joint was created on the face of the previously established circle. The Z-axis dimension was defined as 60 mm, and the component was extruded 50 mm in the Y-axis direction.
- 12. Y-Axis Slider Joint Assembly:** A slider joint assembly was created for the Y-axis rail joint component, with a motion link established between the Y-axis joint and the earlier X-axis joints.
- 13. Circle Features on Y-Axis Rail joint:** A sketch was created on the top edge of the Y-axis rail joint, featuring a circle with a 25 mm diameter, extruded 60 mm along the Z-axis direction. Two additional sketches were made on the top and bottom of the circle, each cut to a depth of 2.5 mm, resulting in a final Z-axis rail direction long 55 mm.
- 14. Z-axis Rail Joint Support:** A side sketch on the Y-axis joint included a rectangle measuring 6.25 mm in the X direction and 55 mm in the Z direction, which was then cut to a depth of 60 mm along the Y-axis direction.
- 15. Z-Axis Rail Joint Component:** An offset plane was created at the top of the circle for the Z-axis rail. A sketch for the Z-axis rail joint component was developed, with dimensions of 53.125 mm in the X direction (to accommodate the CNC machine tool) and 60 mm in the Y direction, which was extruded 20 mm along the Z-axis.
- 16. Z-Axis Slider Joint Assembly:** A slider joint assembly was created for the Z-axis rail joint component.

Adding more parts like a table and end stops to my CNC machine can enhance its functionality and precision.



**Figure 15 : My final work**

I used Fusion 360 to design my hobby CNC machine because Fusion 360 is an integrated cloud-based 3D modeling, computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE) tool developed by Autodesk. Launched in 2013, it has quickly become a favorite among engineers, designers, and makers due to its comprehensive feature set, user-friendly interface, and collaborative capabilities. The software is aimed at professionals and enthusiasts alike, offering tools for product design, mechanical engineering, and manufacturing processes, all within a single platform.

❖ **Key features:**

1. **3D Modeling Capabilities:** Fusion 360 provides a versatile modeling environment that supports various techniques, including parametric modeling, direct modeling, and mesh modeling. Users can create complex geometries and components with ease. The parametric modeling feature allows users to define relationships and constraints among components,

enabling them to make design changes effortlessly. Direct modeling offers flexibility for users who prefer a more intuitive approach, while mesh modeling is ideal for working with scanned objects or freeform designs.

- 2. Simulation and analysis Tools:** One of the standout features of fusion 360 is its simulation capabilities. The software allows users to run structural, thermal, and model analysis, helping to validate designs before physical prototypes are created. Users can simulate real-world conditions, such as stress and strain, to identify potential failures in their designs. This ability to test and refine designs virtually saves time and resources, significantly streamlining the development process.
- 3. Integrated CAM functionality:** Fusion 360 seamlessly integrates CAM tools, enabling users to generate CNC toolpaths directly from their 3D models. The software supports various machining strategies, including milling, turning, and additive manufacturing. Users can set up their toolpaths, simulate machining processes, and export G-code for CNC machines—all from within the same application. This integration is particularly valuable for manufacturers looking to reduce lead times and improve production efficiency.
- 4. Cloud-Based Collaboration:** As a cloud-based platform, Fusion 360 fosters collaboration among team members. Multiple users can access, edit, and review projects in real-time, regardless of their physical location. This feature is especially beneficial for remote teams, as it reduces the friction associated with version control and file sharing. The cloud storage also ensures that users can access their designs from any device with internet connectivity, providing flexibility and convenience.
- 5. Additive Manufacturing Support:** With the rise of 3D printing, Fusion 360 includes features that cater specifically to additive manufacturing. Users can prepare and optimize their designs for 3D printing, ensuring that they meet the requirements for various printing technologies. The software allows for easy modifications to ensure printability, such as adjusting supports and infill patterns, enhancing the overall efficiency of the prototyping process.

## ❖ Use Cases:

Fusion 360 is widely used across different industries and sectors. Some common applications include:

- **Product Design:** Designers leverage Fusion 360 to develop consumer products, electronics, and industrial machinery. Its robust modeling and simulation tools enable rapid iteration and refinement.
- **Mechanical Engineering:** Engineers use Fusion 360 to design components, assemblies, and systems, ensuring that their designs meet technical specifications and performance criteria.
- **Education:** Many educational institutions incorporate Fusion 360 into their curricula, teaching students the principles of design and engineering in a hands-on manner. Its accessibility and user-friendly interface make it an ideal tool for learning.
- **Prototyping:** Makers and hobbyists use Fusion 360 for rapid prototyping, allowing them to create functional models quickly and efficiently. The integration of design and CAM tools facilitates a smooth transition from digital design to physical object.

## ❖ Learning Resources and Community:

Autodesk provides extensive learning resources for Fusion 360 users, including tutorials, webinars, and documentation. The Fusion 360 community is vibrant and supportive, with forums where users can share tips, ask questions, and showcase their projects. Numerous online courses and Youtube channels offer additional training, catering to different skill levels, from beginners to advanced users.

### **Pricing and Accessibility:**

Fusion 360 operates on a subscription model, with different pricing tiers available for individuals, students, and businesses. Autodesk offers a free version for students, educators, and startups, making it accessible to those who are just starting out. This commitment to accessibility has contributed to its popularity, as many users can explore its capabilities without a significant financial investment.

### **Conclusion:**

Fusion 360 stands out as a powerful tool that integrates various aspects of product design, engineering, and manufacturing into a cohesive platform. Its robust modeling capabilities, simulation tools, and cloud-based collaboration features make it an essential resource for professionals across industries. Whether for product



development, educational purposes, or hobbyist projects, Fusion 360 provides the tools necessary to innovate and create effectively. As technology continues to evolve, Fusion 360 remains at the forefront of design and manufacturing solutions, empowering users to bring their ideas to life.

### **3.2 Material Selection:**

For the construction of my hobby CNC machine, I selected aluminum as the primary material due to its favorable properties, including strength, weight, and machinability. Specifically, the alloy chosen is Aluminum 6061-T6, which is known for its excellent mechanical properties and resistance to corrosion.

Given the operating conditions, the machine components are designed to withstand temperatures up to 90°C. At this elevated temperature, the material's strength characteristics are slightly reduced but remain adequate for the intended application.

The approximate material strengths at 90°C for Aluminum 6061-T6 are as follows:

- **Tensile Strength:** Approximately 270-280 Mpa (39,000-41,000 psi)
- **Yield Strength:** Approximately 240-250 Mpa (35,000-36,000 psi)

These values ensure that the frame and structural components of the CNC machine will provide sufficient support and durability during operation, while also allowing for effective machining of various materials, including wood, plastic, and aluminum.

### **3.3 Structural Integrity Calculations:**

#### **Maximum Load Calculation for Aluminum 6061-T6:**

To assess the structural integrity of the CNC machine frame, the maximum load capacity of Aluminum 6061-T6 was calculated based on its yield strength and the cross-sectional area of the components.

#### **Material Properties:**

The yield strength of Aluminum 6061-T6 is approximately 250Mpa.

#### **Area Consideration:**

The effective cross-sectional area of the machine components is 150,000 mm<sup>2</sup> (or 0.15 m<sup>2</sup>)

### **Calculation of Maximum Load:**

Using the formula for maximum load:

$$\text{Max Load} = \text{Area} * \text{Yield Strength}$$

Converting the yield strength to appropriate units:

$$250 \text{ MPa} = 250 * 10^6 \text{ N/m}^2$$

Calculating the maximum load:

$$\text{Max Load} = 150,000 \text{ mm}^2 * 250 * 10^6 \text{ N/m}^2$$

Converting the area from mm<sup>2</sup> to m<sup>2</sup>:

$$= 0.15 \text{ m}^2 * 250 * 10^6 \text{ N/m}^2 = 37,500,000 \text{ N (or 37.5 MN)}$$

Thus, the maximum load that Aluminum 6061-T6 can support with an area of 150,000 mm<sup>2</sup> is approximately 37,500,000 N (37.5 MN). This calculation assumes a uniformly distributed load and that the yield strength is not exceeded. To ensure safety and performance, a safety factor should be applied in practical applications.

### **Volume and Weight Calculation:**

(Density of Aluminum 6061  $\approx 2.7 \text{ g/cm}^3$ )

- **Formula: Volume = Length \* Width \* Height**
- **Formula: Weight = Volume \* Density**

#### **1. Frame Volume and Weight Calculation:**

- $V_{\text{frame}} = 300 \text{ mm} * 500 \text{ mm} * 20 \text{ mm} = 3,000,000 \text{ mm}^3 = 3000 \text{ cm}^3$
- $W_{\text{frame}} = 3000 \text{ cm}^3 * 2.7 \text{ g/cm}^3 = 8,100 \text{ g} \approx 8.1 \text{ kg}$

#### **2. Support Columns Volume and Weight Calculation:**

- **Support column Calculation (for one column):**  
 $V_{\text{column}} = 50 \text{ mm} * 50 \text{ mm} * 80 \text{ mm} = 200,000 \text{ mm}^3 = 200 \text{ cm}^3$

- **Total Volume for Four Columns:**

$$V_{\text{total columns}} = 4 * 200,000 \text{ mm}^3 = 800,000 \text{ mm}^3 = 800 \text{ cm}^3$$

- **Total Weight for Four columns:**

$$W_{\text{total columns}} = 800 \text{ cm}^3 * 2.7 \text{ g/cm}^3 = 2160 \text{ g} \approx 2.16 \text{ kg}$$

### 3. X-Axis Rails Volume and Weight Calculation:

- $V_{\text{rails}} = 450 \text{ mm} * 50 \text{ mm} * 25 \text{ mm} = 562,500 \text{ mm}^3 = 562.5 \text{ cm}^3$
- $W_{\text{x-axis rails}} = 562.5 \text{ cm}^3 * 2.7 \text{ g/cm}^3 = 1518.75 \text{ g} \approx 1.52 \text{ kg}$

### 4. Circular Features Volume and Weight Calculation:

- **Total Volume for all the half circles:**

$$V_{\text{total half circles}} = 0.5 * \pi * (12.5)^2 * (350+140+55) = 133763.1247 \text{ mm}^3 \\ = 133.763 \text{ cm}^3$$

- **Total Weight for all the half circles:**

$$W_{\text{total half circles}} = 133.763 \text{ cm}^3 * 2.7 \text{ g/cm}^3 = 361.16 \text{ g} \approx 0.361 \text{ kg}$$

### 5. Y-Axis Rail Volume and Weight Calculation:

- $V_{\text{y-rail}} = 260 \text{ mm} * 25 \text{ mm} * 25 \text{ mm} = 162,500 \text{ mm}^3 = 162.5 \text{ cm}^3$
- $W_{\text{y-axis rail}} = 162.5 \text{ cm}^3 * 2.7 \text{ g/cm}^3 = 438.75 \text{ g} \approx 0.439 \text{ kg}$

## 4. Future possibilities how can I develop my Hobby CNC machine:

The development of a hobby CNC machine follows a structured approach, encompassing several key stages to ensure functionality and precision. The following sections outline the detailed process:

### 1. Incorporate Spindle and Electronics:

Next, focus on the integration of the spindle and electronic components:

- **Spindle Mounting:** Design a robust mounting bracket for the spindle/router, ensuring it is adjustable and securely fastened.
- **Electronics Enclosure:** Create a sketch for an enclosure that houses the control electronics, ensuring accessibility for wiring and maintenance.

### 2. Add Motion Mechanisms:

The addition of motion mechanisms is essential for coordinated movement:

- **Lead screws and motors:** Design the mounting points for lead screws and stepper motors, taking care to ensure proper alignment and support.
- **Motion Links:** Integrate motion links that connect the spindle to the lead screws, enabling coordinated movement along the X, Y, and Z axes.

### 3. Prototype and Test:

Prototyping allows for verification of the design:

- **Create Prototypes:** if feasible, 3D print or fabricate prototypes of key components to test for fit and functionality.
- **Assembly:** Assemble the CNC machine according to the finalized design, with particular attention to alignment and securing joints.

### 4. Calibration and Testing:

Calibration is critical for optimal performance:

- **Calibration:** upon assembly completion, calibrate the CNC machine to verify the accuracy of movements along all axes.
- **Test cuts:** Conduct test cuts using various materials to fine-tune settings and ensure smooth operation.

### 5. Expand Capabilities:

Finally, consider future enhancements:

- Explore the addition of features such as a vacuum table for improved material hold-down, a dust collection system, or additional tooling options to increase versatility.

## 5. Economical calculations:

### Parts list for Hobby CNC machine:

#### 1. Frame and structure:

- **Aluminum Extrusions:**
  - 4 x 300 mm lengths (for the frame sides).

- 2 x 500 mm lengths (for the frame front and back).
- **Support Columns:**
  - 4 x 50 mm x 50 mm x 80 mm ( cut from larger extrusions or purchased as pre-cut pieces).
  - **Corner Brackets:**
    - 8 brackets (for securing the frame and columns)
  - **Feet or Mounting Pads:**
    - 4 feet(to stabilize the frame on a work surface)

## 2. Linear Motion Components:

- **Linear Rails:**
  - 2 x 450 mm lengths (for X-axis motion)
  - 2 x 260 mm lengths (for Y-axis motion)

## 3. Motors:

- **Stepper Motors:**

### **Creality Stepper Motor:**

- **Torque:** Approximately (0.45 Nm) to (0.6 Nm), depending on the specific model.
- **Current Raing:** Usually around 1.5A to 2.0A per phase.
- **Use case:**
  - **3D Printing:** These motors ayre widly used in 3D printers, providing good precision and control for the print head.
  - **CNC machines:** Suitable for light to moderate CNC applications, particularly when cutting softer materials like plastics, wood, and light metals.
  - **Robotics:** Often utilized in various robotic applications requiring precise movement.

- **Motor mounts:** 3 motor mounts (to secure motors to the frame).

#### 4. Motion Control:

- **CNC Controller Board:**
  - 1 x Arduino with GRBL shield or similar CNC controller.
- **Motor Drivers:**
  - 3 x A4988 or DRV8825 stepper motor drivers.

#### 5. Power Supply:

- **Dc Power Supply:**
  - 1 x 25V, 10A power supply(suitable for stepper motors)

#### 6. Spindle or Router:

- **Spindle Motor or Dremel Tool:**
  - 1 x 300W spindle or Dremel for cutting
- **Spindle Mount:**
  - 1 ( to securely hold the spindle)

#### 7. Electronics and Wiring:

- **Limit Switches:**
  - 3 x limit switches (for homing and safety)
- **Wiring and Connectors:**
  - Sufficient wiring for motors, power supply, and limit switches.
- **Cooling Fans:**
  - 1 or 2 (if needed for electronics)

#### 8. Miscellaneous Components:

- **V-bits or End Mills:**
  - 5 assorted bits (for different materials)
- **Safety Gear:**
  - Safety glasses and dust mask
- **Calibration Tools:**
  - 1 digital caliper or ruler for setup

#### Summary of Components:

- **Aluminum Extrusions:**
  - 4 x 300 mm



- 2 x 500 mm
- **Support Columns:**
  - 4 x 50 mm x 50 mm x 80 mm
- **Linear Rails:**
  - 2 x 450 mm
  - 2 x 260 mm
- **Crealty stepper Motor:**
  - 1 unit
- **CNC Controller:**
  - 1 unit (arduino + GRBL)
- **Power Supply:**
  - 1 unit (24 V, 10 A)
- **Spindle Motor:**
  - 1 unit (300 W spindle)
- **Limit Switches:**
  - 3 units
- **Miscellaneous Fasteners:**
  - Screws, nuts, and bolts for assembly

**Approximate Costs For the CNC machine parts:**

**Approximate Costs for Aluminum Extrusions:**

❖ **Aluminum Extrusions (200 or 2040 series):**

- **4 x 300 mm lenghts:**
  - Approximately \$3 to \$5 each, so around \$12 to \$20 total.
- **2 x 500 mm lenghts:**
  - Approximately \$5 to \$8 each, so around \$10 to \$16 total.

In hungary, I can purchase aluminum extrusions from various suppliers, both online and in physical stores. Here are a few options:

1. **Local Hardware Stores:** Larger chains like OBI or Bauhaus often carry aluminum extrusions.

2. **Specialty Metal Suppliers:** Companies like Aluform or Aluprof specialize in aluminum products and may offer a wide range of extrusions.
3. **Online Marketplace:** Websites like eMAG or Aliexpress can have aluminum extrusions available for shipping to Hungary.
4. **Industrial Suppliers:** Look for industrial suppliers or manufactures that focus on metal fabrication, such as BÖHLER edelstahl.
5. **CNC supply Stores:** Stores focused on CNC machinery and parts may also have aluminum extrusions.

### Approximate Costs for Corner Brackets:

#### ❖ Metal Corner Brackets:

- **Standard Size (typically 90 mm x 90 mm ):**
  - Approximately \$1 to \$3 each, depending on the material (steel, aluminum) and brand.
- **Total Estimated Cost:**
  - **For 8 brackets:** Approximately \$8 to \$24.
- **Considerations:**
  - **Material Quality:** Aluminum brackets may be more expensive but lighter, while steel brackets are typically stronger and might be cheaper.
  - **Local Suppliers:** Prices can vary by region and supplier, so It's a good idea to check local hardware stores or online retailers for the best deals.

I can buy metal corner brackets (typically 90 mm x 90 mm) from several places in Hungary:

1. **Local Hardware Stores:** Chains like Bauhaus, OBI, or Praktiker usually carry a range of metal brackets.

2. Amazon or eBay: If you're open to international shipping, these platforms can have a variety of options available.

### **Approximate Costs for Feet or Mounting Pads:**

#### **❖ Adjustable Leveling Feet:**

- **Approximately \$3 to \$10 each, depending on the size and quality.**
- **Total Estimated Cost:**
  - For 4 adjustable levelling feet: Approximately \$12 to \$40.
- **Considerations:**
  - **Material and Size:** Costs may vary based on the size, weight capacity, and material (rubber, plastic, or metal).
  - **Local Suppliers:** Check local hardware stores or online retailers for competitive prices and bulk options.
  - **Specialty Feet:** if you need feet with specific features (like anti-vibration or extra grip), those may cost more.

### **Approximate Costs for Linear Rails:**

#### **❖ Linear Rails (Hardened Steel or Aluminum):**

- **2 x 350 mm rails:**
  - Approximately \$10 to \$20 each, so around \$20 to \$40 total.
- **1 x 140 mm rail:**
  - Approximately \$5 to \$15.
- **2 x 55 mm rails:**
  - Approximately \$3 to \$10 each, so around \$6 to \$20 total.

I can buy linear rails (hardened steel or aluminium) in Hungary from several sources:

1. **Local Hardware Stores:** Larger chains like Bauhaus, OBI, or Praktiker may have a selection of linear rails, though availability can vary.
2. **Online Retailers:** Websites like eMAG or Alza often stock linear motion components, including linear rails.
3. **Specialty Suppliers:** Companies like KMS or Aluform focus on metal products and may offer a range of linear rails.

4. **CNC and Robotics Supply Stores:** Stores that cater specifically to CNC and robotics enthusiasts may have a good selection of linear rails, such as Robotshop or Maker shop.
5. **Amazon or ebay:** If you're open to international shipping, these platforms typically have various options available.

#### **Approximate Costs for Creality Stepper Motors:**

##### **❖ Stepper Motor:**

- **Price Range:** Approximately \$15 to \$30 each.
- **Consideration:**
  - **Supplier Variations:** Prices may vary depending on whether you buy from local retailers, online marketplaces (like Amazon or eBay), or specialized suppliers.
  - **Bundles:** Sometimes you can find deals where stepper motors are sold in bundles or kits, which may offer savings.
  - **Shipping Costs:** If ordering online, factor in potential shipping costs.

I can buy Creality stepper motors in Hungary from several places:

1. **Local Electronics Stores:** Larger electronics retailers may carry creality products or similar stepper motors.
2. **3D Printing Supply Stores:** Specialized stores like 3D Nyomtatás or 3D print, Hungary often stock Creality parts and accessories, including stepper motors.
3. **Online Marketplaces:** Websites such as eMAG, Alza, or eBAY often have a variety of Creality stepper motors available.
4. **Amazon:** If you're open to international shipping, Amazon typically has a wide selection of creality products.
5. **Official Creality Website:** You can check the official Creality store or authorized distributors for purchasing options.

#### **Approximate Costs for Motor Drivers:**

The approximate cost for three A4988 or DRV8825 stepper motor drivers would typically be around \$4.50 to \$15. Each driver usually costs between \$1.5 and \$5.

I can buy A4988 or DRV8825 stepper motor drivers in Hungary from several sources:

1. **Local Electronics Stores:** Stores that specialize in electronics components may carry these drivers.
2. **Online Retailers:** Websites like eMAG and Alza often have a variety of electronic components, including stepper motor drivers.
3. **3D Printing Supply Stores:** Shops like 3D Nyomtatás or other 3D printing specialists often stock common drivers like A4988 and DRV8825.
4. **International Online Marketplaces:** Sites like eBAY, AliExpress, or Amazon usually offer stock common drivers like A4988 and DRV8825.
5. **Electronics Distributors:** Companies like RS Components or Mouser Electronics typically have a range of electronic components, including these drivers.

#### **Approximate Costs for DC Power Supply:**

A 24V, 10A DC power supply typically costs around \$25 to \$50.

#### **Approximate Costs for Spindle Motor:**

A 300W spindle motor typically costs between \$40 and \$100.

#### **Approximate Costs for Limit Switches:**

The approximate cost for three limit switches is around \$5 to \$15 total. Individual limit switches usually range from \$1 to \$5 each, depending on the type and brand. Checking various electronics suppliers will help you find the best prices.

I can find a 24V, 10A DC power supply, 300W spindle motor, and limit switches in Hungary from several sources:

1. **Local Hardware and Electronics Stores:**
  - **Bauhaus**
  - **OBI**
  - **Praktiker**

## **2. Online Retailers:**

- **eMAG:** A popular site for various electronics and hardware.
- **Alza:** offers a wide range of electrical components.
- **Coolmod:** Specializes in electronics and often has a variety of components.

## **3. 3D Printing Supply Stores:**

- **3D Nyomtatás:** Specializes in 3D printing components, including spindles and power supplies.
- **3D Print Hungary:** Another good option for CNC and 3D printing parts.

## **4. Specialty Electronics Suppliers:**

- **RS Components:** A reliable source for various electronic components.
- **Mouser Electronics:** Offers a wide range of electronic supplies, including power supplies and motors.

## **5. International Marketplaces:**

- **Amazon:** If you're open to international shipping, you can often find good deals.
- **eBAY:** Frequently has a variety of electrical components.

## **Approximate Costs for Spindle Mount:**

A spindle mount typically costs between \$10 and \$30, depending on the material, design, and compatibility with the spindle size.

I can find a spindle mount in Hungary from several sources:

### **1. Local Hardware Stores:**

- **Bauhaus**
- **OBI**
- **Praktiker:** Check their tool sections for spindle mounts.

### **2. Online Retailers:**

- **eMAG:** Offers a variety of tools and accessories.
- **Alza:** A good option for various hardware components.

### **3. 3D Printing Supply Stores:**

- **3D Nyomtatás:** May have specific mounts for 3D printing and CNC applications.



- **3D Print Hungary:** Another store focusing on CNC and 3D printing parts.
4. **Specialty Suppliers:**
    - **Rs Components or mouser Electronics:** While they may have a broader range of electronics, they often carry accessories like spindle mounts.
  5. **Amazon or ebay:** If you're comfortable with international shipping, these platforms typically have a variety of spindle mounts available.

### **Approximate Costs for Wiring and Connectors:**

The cost for sufficient wiring and connectors for motors and power supplies typically ranges from \$10 to \$30, depending on the type and length of wiring needed, as well as the quantity and quality of connectors.

I can find a spindle mount in Hungary from several sources:

1. **Local Electronics Stores:**

- **Conrad Electronics:** Offers a wide range of electronic components, including wiring and connectors.
- **Bauhaus or OBI:** Some hardware sections may have basic wiring and connectors.

2. **Online Retailers:**

- **eMAG:** A good selection of wiring and connectors.
- **Alza:** Often stocks various electronic components, including wiring supplies.

3. **3D Printing and CNC Supply Stores:**

- **3D Nyomtatás:** They may carry specific wiring solutions for CNC applications.
- **3D Print Hungary:** Another option for electronics related to 3D printing and CNC.

4. **Specialty Electronics Suppliers:**

- **RS Components or Mouser Electronics:** They typically have a comprehensive selection of wiring and connectors.

5. **Amazon or eBay:** if you're comfortable with international shipping, these platforms often have a wide range of options.

**The total cost of the whole CNC machine is approximately between \$177.5 to \$435**

## **6. Summary:**

My project focuses on designing a 3D model for a simple 3-axis Hobby CNC machine using Fusion 360, prioritizing ease of assembly, material fabrication, and cost-effectiveness.

### **3D Model Development Process:**

1. **Frame Creation:** Designed a 300 mm x 500 mm frame and extruded it.
2. **Support columns:** Added four support columns, each 50 mm x 50 mm and 80 mm tall.
3. **X-axis rails:** Created and extruded X-axis rails to connect the support columns.
4. **Circle Features:** Incorporated circles on the X-axis rails for movement.
5. **Joint support:** Developed joint structures to enhance stability.
6. **X-axis movement Components:** Designed and assembled joint components for movement.
7. **Y-axis Development:** Constructed Y-axis components, ensuring coordinated movement through slider joints.

### **Material Selection:**

Aluminum 6061-T6 was chosen for its strength, lightweight, and machinability, with a yield strength suitable for temperatures up to 90°C.

### **Structural Integrity:**

Calculated the maximum load capacity of the frame, estimating it can support approximately 37.5 MN, ensuring safety with appropriate factors.

### **Volume and Weight Calculations:**

Conducted calculations for the frame and components, determining the overall weight and volume to ensure material efficiency.

### **Future Development:**

Plans include integrating a spindle, electronics, and motion mechanisms, prototyping key components, calibrating the machine, and exploring additional features like vacuum tables and dust collection systems to enhance functionality and versatility.

I used Fusion 360 to design my hobby CNC machine because it's versatile modeling tools and integrated simulations. These features not only streamlined the design process but also enhanced the machine's functionality and reliability.

### **7. References:**

- ([History of CNC Technology – EngineeringTechnology.org](#))
- ([How Do CNC Machines Work? - Marshall Manufacturing - Medical Device Manufacturing](#))
- ([15 Types of CNC Machines Commonly Used in Manufacturing | Machinery Network](#))
- ([15 Main Types of CNC Machines Explained - CNCsourced](#))
- ([Top Features of CNC Machines Explained](#))
- ([The Future of CNC: 7 Emerging Trends to Watch](#))