DCW30383

CNC MACHINING

3 Axis CNC Router (Operation & Components)

Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA)

e-Book

3 Axis CNC Router (Operation & Components)

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SYNOPSIS

This **e-Book** serves as an additional reference for students of Diploma in Wood-Based Technology who are enrolled in the *DCW30383 CNC Machining* subject in Semester 3.

In this **e-Book** , students will learn about revolution of CNC Machine, type of CNC Machine , Software used , advantages and disadvantages , safety of CNC Machine , compenent of CNC Machine and operation of CNC Machine.

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ABOUT THE AUTHOR

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- She is an alumnus of the Diploma in Wood-Based Technology Programme at Polytechnic Sultan Salahuddin Abdul Aziz Shah who graduated in 2009.

- Then, she continued her studies to the Bachelor's Degree, Bachelor of Wood Science and Technology at Universiti Putra Malaysia and successfully completed her studies in 2014.

- She started her career as a Lecturer of Diploma in Wood-Based Technology Programme at Polytechnic Sultan Salahuddin Abdul Aziz Shah in February 2015.

- Armed with knowledge and experience in the field of wood science and technology for 17 years, she is now the Head of the Programme for the DBK Programme at PSA.

ABOUT THE AUTHOR

Hamdi Bin Haji Mawardi

- He is also an alumnus of the Diploma in Wood-Based Technology Programme at Polytechnic Sultan Salahuddin Abdul Aziz Shah who graduated in 2002.

- Then, he continued his studies to the Bachelor's Degree, Bachelor of Public Management at Northern University of Malaysia and successfully completed her studies in 2013.

- He started his career as Industrial Training Officer at Malaysian Timber Industry Board from 2003 until 2015 and currently as a Lecturer of Diploma in Wood-Based Technology Programme at Polytechnic Sultan Salahuddin Abdul Aziz Shah in February 2015 and present.

- Armed with knowledge and experience in the field of wood processing and technology for 24 years, he is now specializing in product making and CNC Machining Technology.

CHAPTER 1 :

The CNC Machine

1.1 Revolution of CNC Machining

1950s

- The concept of CNC emerged in the aerospace industry, with the first machines using punched tape for control. These early machines were large, costly, and primarily used for metalworking.

1970s

- CNC technology spread to various industries, including woodworking, but remained limited to large manufacturers due to high costs.

1980s

- Significant improvements in computing made CNC machines more affordable and compact. This decade marked the beginning of CNC adoption in larger wood manufacturing, allowing more precise and complex woodworking tasks.

1990s

- Advancements in software (like CAD/CAM) simplified the design-to-production process, further encouraging CNC use in the wood industry. Smaller businesses began investing in CNC machines as they became increasingly accessible.

2000s

- CNC machines for woodworking saw major growth, with costs decreasing and functionality expanding. Smaller, desktop CNC machines also became available, sparking interest among hobbyists and small workshops.

2010s and beyond

- CNC wood machining became widely accessible, with digital modeling and cloud-based software making it easier to create and share designs. Innovations like 3D carving and multi-axis CNCs allowed for even more complex and creative woodworking possibilities, solidifying CNC's role in the modern wood industry.

1.2 Type of CNC Machine

1. CNC Router

- A CNC router is a computer-controlled machine used to cut and shape materials like wood, plastic, and foam. It works by moving a rotating cutting tool (or router bit) over a flat piece of material along X, Y, and Z axes. This allows it to carve, engrave, or cut out complex shapes and patterns based on a digital design.
- CNC routers are commonly used in woodworking and sign-making to create detailed designs quickly and accurately. They are faster than CNC mills and ideal for large, flat materials but are generally less suited for cutting hard metals or achieving ultra-fine precision.

2. CNC Milling

- A CNC milling machine is a computer-controlled machine designed for high-precision cutting, shaping, and drilling of harder materials like metals, as well as wood and plastics. It uses rotating cutting tools, called end mills or cutters, which move along multiple axes (typically X, Y, and Z) to carve out complex shapes and details.
- CNC milling is ideal for creating 3D parts, intricate components, and prototypes with high accuracy. Unlike CNC routers, which are better for softer materials, CNC mills are more powerful and versatile, making them suitable for tasks that require fine detail and durability. They're commonly used in manufacturing metal parts, machinery components, and prototypes.

3. CNC Lathe

- A CNC lathe is a computer-controlled machine used for making cylindrical or round parts by rotating the material (called the workpiece) along a central axis. While the workpiece spins, a stationary cutting tool moves along it, shaping the material by removing layers. This type of machining is great for creating symmetrical objects, such as shafts, screws, and pipes.
- CNC lathes operate mainly on two axes (X and Z) and are very efficient for producing smooth, detailed curves or contours. They are commonly used in metalworking but can also handle other materials like wood and plastic. Because of their precision, CNC lathes are ideal for parts that need to be perfectly round or have complex curves.

1.3 Software

1. CAD (Computer-Aided Design)

1. In CAD, you can draw complex **2D** shapes or **3D** models, specifying all dimensions, curves, and features. This digital model represents the final product and allows for modifications and refinements.

AutoCAD

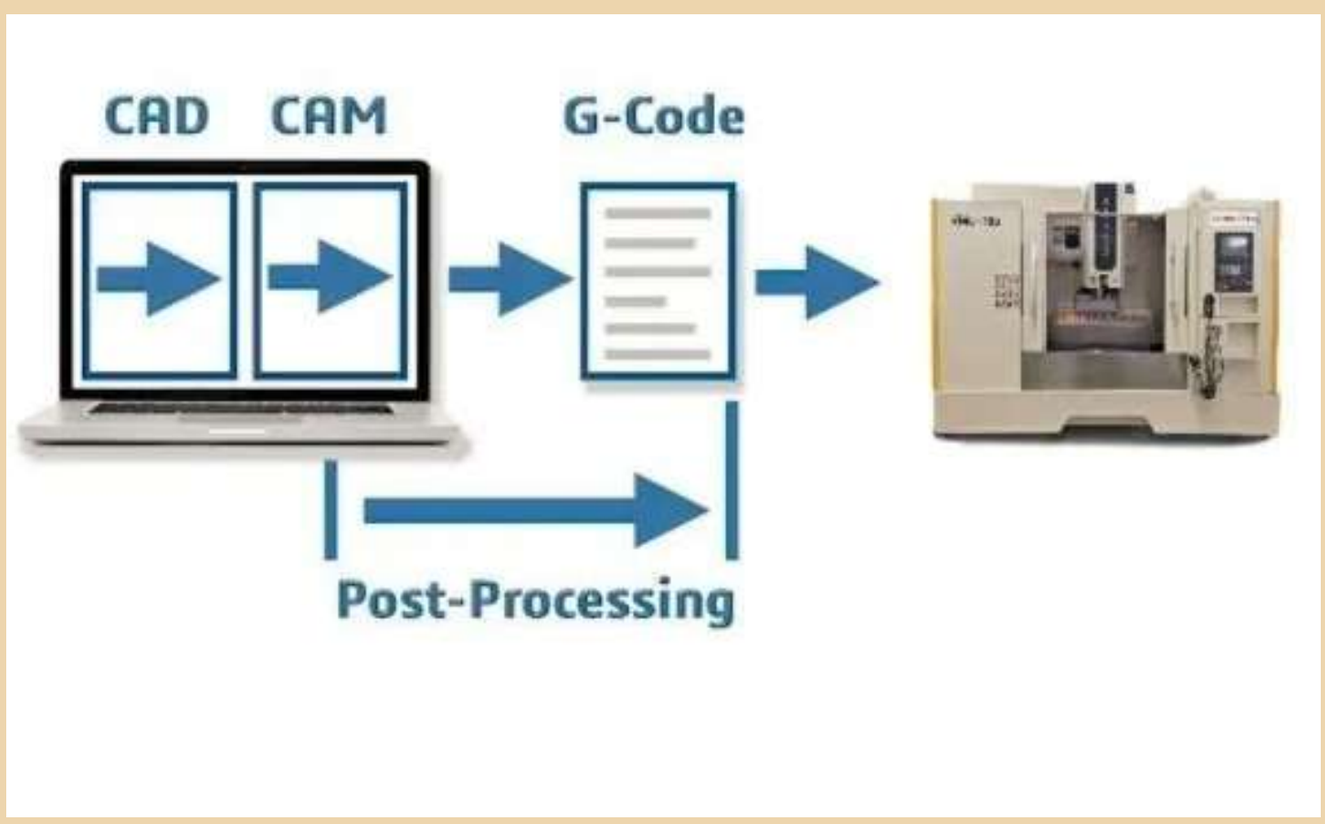
2. CAM (Computer-Aided Manufacturing)

1. **CAM** software reads the CAD (design) file and converts it into toolpaths, or exact paths
2. **CAM** helps choose the best cutting tools and adjusts speeds for different wood types, ensuring smooth cuts and reducing wear on the tools.
3. **CAM** can run a virtual cut of the design, allowing you to see how the machine will perform and catch any errors before it starts cutting wood.
4. Once ready, **CAM** sends these instructions directly to the CNC machine, guiding it step-by-step to create the design.

ALPHACAM

3. Post Processor

- Post-processor is a tool in CAM software that **translates** the toolpaths (cutting instructions) into a specific language the CNC machine understands.
- Each CNC machine can have different codes and formats, so the post-processor customizes the instructions to match the exact type of machine you're using.
- a post-processor "translates" the cutting plan from CAM into a language your CNC machine can read and follow.



1.4 Advantages and Disadvantages

CNC wood machines offer great benefits, such as high precision, faster production, and the ability to create identical pieces easily. However, they also come with challenges like high costs, the need for skilled operators, and maintenance requirements.

ADVANTAGES	DISADVANTAGES
High Precision : CNC machines follow digital designs very accurately, so they produce clean, precise cuts.	**High Initial Cost :** CNC machines can be expensive to purchase and install, which may be a barrier for smaller businesses or hobbyists.
Efficiency : They can work quickly and handle complex shapes, speeding up production compared to manual work.	**Skill Requirement :** Operating and programming CNC machines requires specialized knowledge and skills, which can involve training and experience.
Consistency : CNC machines produce identical pieces every time, which is ideal for mass production and maintaining quality.	**Maintenance Needs :** CNC machines require regular maintenance to keep them in good working condition, and repairs can be costly and time-consuming.
Safety : Automated processes reduce the risk of injury associated with manual cutting and handling tools.	**Taking up too much space :** This can increase operational costs since larger spaces often require more heating, cooling, and lighting, impacting the overall budget.

CHAPTER 2 :

Safety in CNC Machine

SAFETY PRECAUTIONS

WHAT IS SAFETY ?

- Safety is all about protecting yourself and others from potential hazards, especially when working with machines or tools. It involves following certain rules, using protective gear, and being mindful of your surroundings to avoid accidents or injuries.

TWO GENERAL SAFETY RULE FOR CNC MACHINES

1. **Never** operate a CNC machine without proper training or consulting the specific operator's manual for that particular machine and control type.
2. **Never** attempt to program a CNC machine without proper training or consulting the specific programmer's manual for that particular machine and control type

SAFETY FLOW

BEFORE → **DURING** → **AFTER**

- Prepare by assessing potential risks, wearing protective gear, and ensuring that equipment and surroundings are safe. This is the planning stage to prevent accidents before they happen.
- Stay alert and follow safety guidelines carefully. Use equipment properly, stay focused on tasks, and watch for any unexpected hazards.
- Once the task is done, clean up the workspace, safely store tools or equipment, and report any issues. This helps maintain a safe environment for future work.

SAFETY IN CNC MACHINE

1. MATERIAL | **2 MACHINING** | **3. OPERATION**

2.1

1. MATERIAL

1. Identifying dimensions is essential in CAD/CAM design.
2. Following a clear design program according to the plan
3. Ensure the worktable is free of dust, chips, oil, or any debris. A clean surface helps secure the workpiece properly, preventing it from shifting during machining.
4. Always start by putting on personal protective equipment (PPE)

PPE examples

2.2

2. MACHINING

1. Check that tools are properly calibrated and aligned. Incorrect tool calibration can lead to inaccurate cuts or tool breakage.
2. During CNC machining, it’s crucial to monitor rotation speed (spindle speed) and feeding speed (feed rate) in real-time, as improper settings can lead to issues with quality, safety, and equipment durability.

Here’s what to be alert to and the causes and effects:

CAUSE	EFFECTS
Setting the spindle speed too high for the material or tool.	• This can generate excess heat, leading to material melting (in plastics) or burning (in wood), and causing poor surface finishes.
Setting the spindle speed too low.	• Low speeds can make cutting inefficient, causing the tool to drag through the material instead of cutting cleanly. This leads to rough edges, longer machining times, and additional strain on the spindle, which may reduce the machine’s lifespan.
Feeding the tool too quickly across the material.	• High feed rates can overload the tool, causing it to chip or break, especially in harder materials. This also results in poor surface finishes, inaccuracies, and rough cuts, as the tool may skip across the surface.
Using a high feed rate with a low spindle speed, or vice versa, which is not optimized for the material.	• This imbalance can cause chatter (vibrations), resulting in uneven cuts, poor surface quality, and increased wear on the tool and machine.

2.3

3. OPERATION

1. Operating a CNC machine requires **careful attention** to detail to ensure safety, precision, and efficiency.
2. **Technical Knowledge:** A trained operator understands the basics of CNC programming (like G-code) and can interpret CAD/CAM designs. They know how to set up and adjust parameters such as spindle speed, feed rate, and tool paths for different materials and jobs.
3. **Manual handling** is an important aspect of CNC machine operation, despite the high degree of automation involved in CNC processes.

CNC MACHINE SAFETY SYSTEM

- The built-in safety system on a CNC machine includes guards and protective devices which should be securely fitted and always kept in position while the machine is being used. It may include:

SAFETY SYSTEM	APPLICATIONS
Emergency Stop Button	Used to shut down the machine immediately. It is located on the control panel and at other points on the machine.
Soundproof Casing	Reduces noise emission generated by the operating section and protects the operator from the risk of flying objects or tool fragments.
Curtain Guards	Made of PVC and designed to protect the operator from the risk of airborne chips or tool fragments.
Guard Fence	It protects the operator from the risk of interference with moving parts. The guard may be of an open type or made of mesh.
Contact Mats	When the operator stands on the mat, the machine stops immediately, protecting the operator from moving parts of the machine.

CHAPTER 3 :

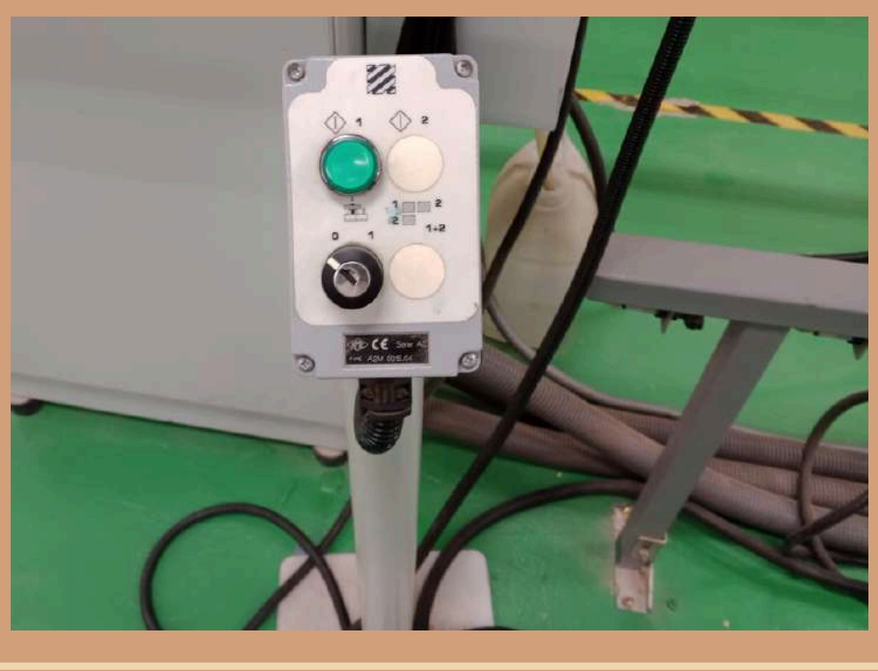
Component of CNC Machine

Component of CNC Machine

- A CNC machine has several key components that work together to achieve precise machining. The **Control Panel** is the brain, loading and executing instructions. **The Machine Bed** and **Worktable** provide stability and hold the workpiece securely. The **Spindle** and **Cutting Tool handle** the actual material removal, with adjustable speed and precision. Axes allow movement in multiple directions, while the Drive System controls this movement. The Coolant and Lubrication Systems keep the machine cool and functioning smoothly, while the Enclosure protects operators from debris, noise, and hazards.

COMPONENT	APPLICATION
1. Air Compressor 	1. Blows air to cool down the cutting tool, reducing heat and preventing tool wear. 2. Powers pneumatic tools and attachments, enabling automated tool changes and other functions. 3. Assists in clamping and holding materials securely in place with vacuum systems.
2. Dryer 	1. It removes moisture from compressed air, preventing water vapor from reaching the machine. This is crucial because moisture can corrode metal parts, damage pneumatic tools, and reduce the lifespan of the machine. 2. Dry air keeps dust and wood particles from clumping together, helping maintain clear airflow for dust and chip removal. This contributes to cleaner, more reliable operation.
3. Pressure Tank 	1. Helps maintain a stable air pressure, preventing fluctuations that could impact the machine's performance, such as during tool changes or high-demand operations. 2. Provides consistent airflow for functions like chip clearing, tool cooling, and clamping, leading to smoother and more reliable machine operation.

COMPONENT	APPLICATION
4. Vacuum Pump 	1. Creates suction to hold down the workpiece on the machine's bed, keeping it firmly in place during cutting. This helps prevent shifting or slipping, ensuring precise cuts. 2. It allows for fast, efficient clamping of materials without the need for manual clamps or fixtures, which saves time when switching between workpieces. 3. By securely holding materials in place, it reduces the risk of movement-related accidents during machining.
5. Star Delta 	1. Star-delta reduces the initial current drawn by the motor when starting up, which protects the electrical system from high surge currents that could cause damage or tripping. 2. It provides a gradual increase in motor speed. The motor initially starts in the "**star**" configuration (**low voltage across windings**), which reduces torque. After a brief period, it switches to the "**delta**" configuration (**full voltage**), allowing the motor to reach full speed smoothly.
6. Waltz Stabilizer 	1. Reduces vibrations generated during high-speed machining. This helps maintain precision and prevents tool chatter, which can degrade cut quality. 2. It helps the CNC machine remain stable even at higher speeds, making it ideal for precision work or working with harder materials. 3. The stabilizer is especially useful when performing intricate or high-tolerance work, where maintaining consistent accuracy is essential.
7. Air Regulator 	1. The regulator prevents excessive air pressure that could damage sensitive parts, like pneumatic tools or actuators, helping maintain their durability. 2. Regulating air pressure minimizes unnecessary air consumption, which can help lower energy costs and extend the life of the air compressor.

COMPONENT	APPLICATION
8. Control Panel 	1. The control panel allows operators to start, stop, pause, and reset the machine, as well as select specific programs and settings. 2. Operators can input or load CNC programs (G-code) directly, enabling precise control over the machine's cutting, drilling, or milling operations. 3. Alerts operators to any faults, errors, or safety concerns, and often includes diagnostic features to troubleshoot issues efficiently.
9. Control Tower 	1. Allows operators to monitor multiple CNC machines or processes from a single location, displaying real-time data like machine status, productivity metrics, and operational issues. 2. Operators can remotely start, stop, or adjust machine parameters for any CNC machine connected to the tower, improving flexibility and response times, especially in large facilities.
10.Vacuum Padle 	1. Vacuum paddles create a strong suction to hold down workpieces firmly on the machine’s bed. 2. These paddles can adapt to different shapes and sizes of materials, making them ideal for handling irregular or non-flat workpieces without damaging them. 3. They allow for fast loading and unloading of materials, which can improve production efficiency by minimizing setup times between jobs.
11. Mobile Jog 	1. Operators can move the machine axes without being directly at the main control panel. 2. The operator can be closer to the work area while adjusting the machine, providing a better view for precise alignment and setup, especially for complex or large pieces.

COMPONENT	APPLICATION
12. Work Table 	1. The work table provides a flat, stable surface for holding the workpiece, ensuring it remains securely positioned during machining. 2. It often includes slots, holes, or clamps to attach fixtures, jigs, or vacuum systems, allowing for flexible and secure material clamping. 3. Many CNC work tables are equipped with vacuum hold-down systems, especially in woodworking CNC machines, allowing for quick, secure, and even pressure on flat materials.
13. Main Spindle 	1. The spindle rotates the cutting tool at variable speeds, enabling it to cut, mill, or drill into the workpiece with the necessary force and precision. 2. Provides the necessary power and torque to the cutting tool, which is essential for machining different materials, from soft wood to hard metals. 3. CNC spindles have adjustable speeds to suit various materials and tasks. Higher speeds are typically used for soft materials and fine details, while lower speeds are better for harder materials or heavy cuts.
14. Tool Magazine 	1. Holds a variety of tools, such as drills, end mills, and taps, that are needed for different machining tasks, allowing for quick access when switching between operations. 2. Each tool can be pre-measured and calibrated, so the machine knows the exact dimensions and offsets of each tool. This enhances precision and reduces the need for recalibration after each tool change.
15. Drilling Head 	1. The drilling head is equipped to make accurate, clean holes at specific locations on the workpiece, essential for tasks like bolt holes, dowel holes, or mounting points. 2. The drilling head can be programmed to drill to precise depths, which is useful for creating consistent hole depths or for blind holes (holes that do not go all the way through the material). 3. Optimized for rapid drilling cycles, the drilling head allows for quick hole creation, which is particularly useful in high-production environments where speed is crucial.

CHAPTER 4 :

Operation in CNC Machine

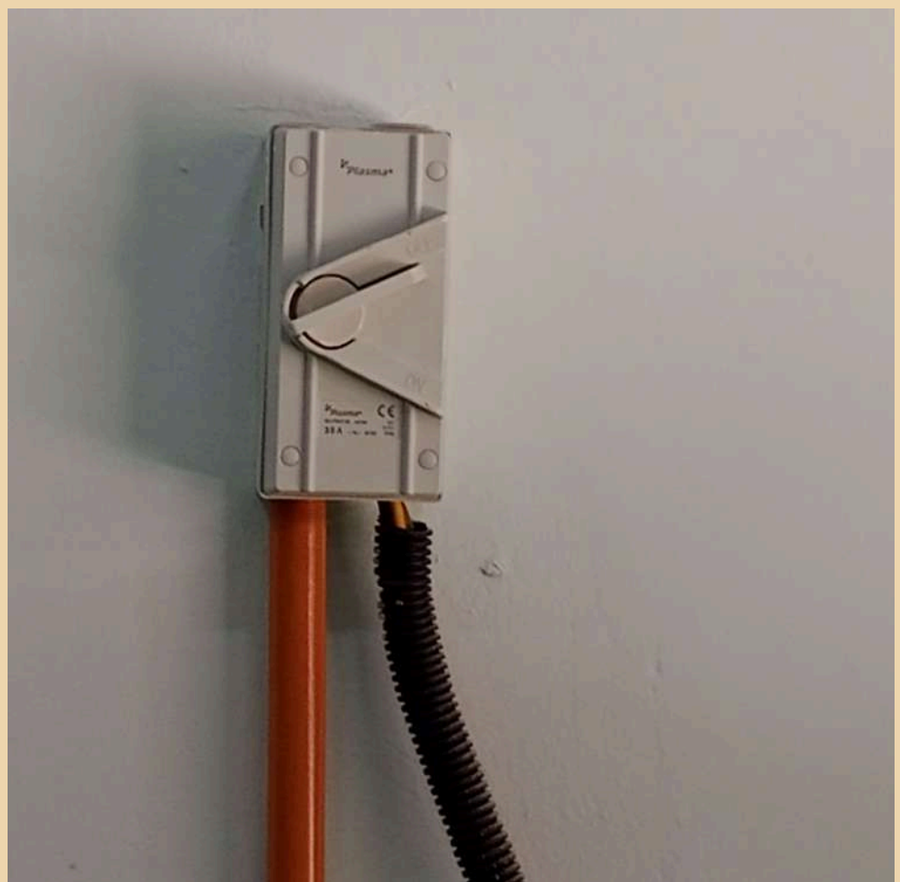
Operation in CNC Machine

- To operate a CNC machine, you set up the machine, choose the right tools, load the material, and input the design program. The CNC machine then follows these instructions automatically, creating parts with minimal human effort. This automation boosts efficiency and reduces mistakes, making CNC machining valuable in manufacturing and product design.

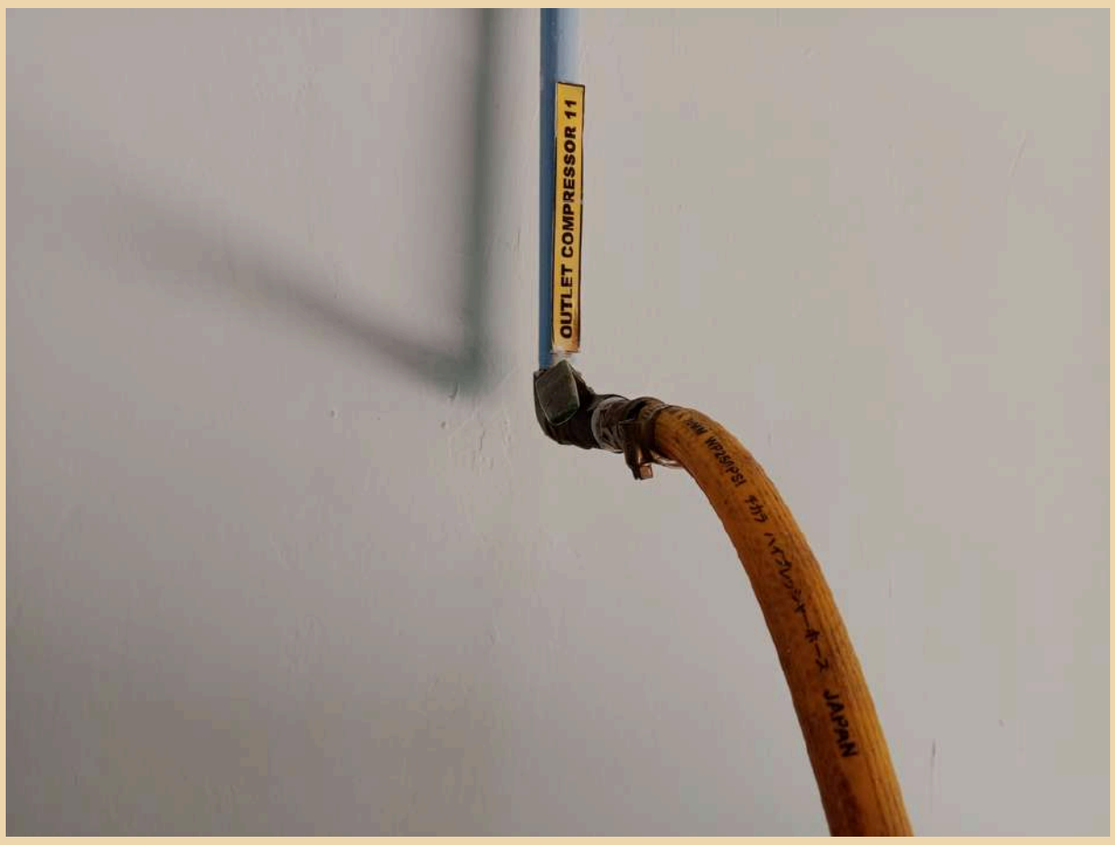
1. Machine Start-Up

1. Ensure that the valve located beneath the pressure tank is **fully closed** before starting the operation."

2. Switch on the power



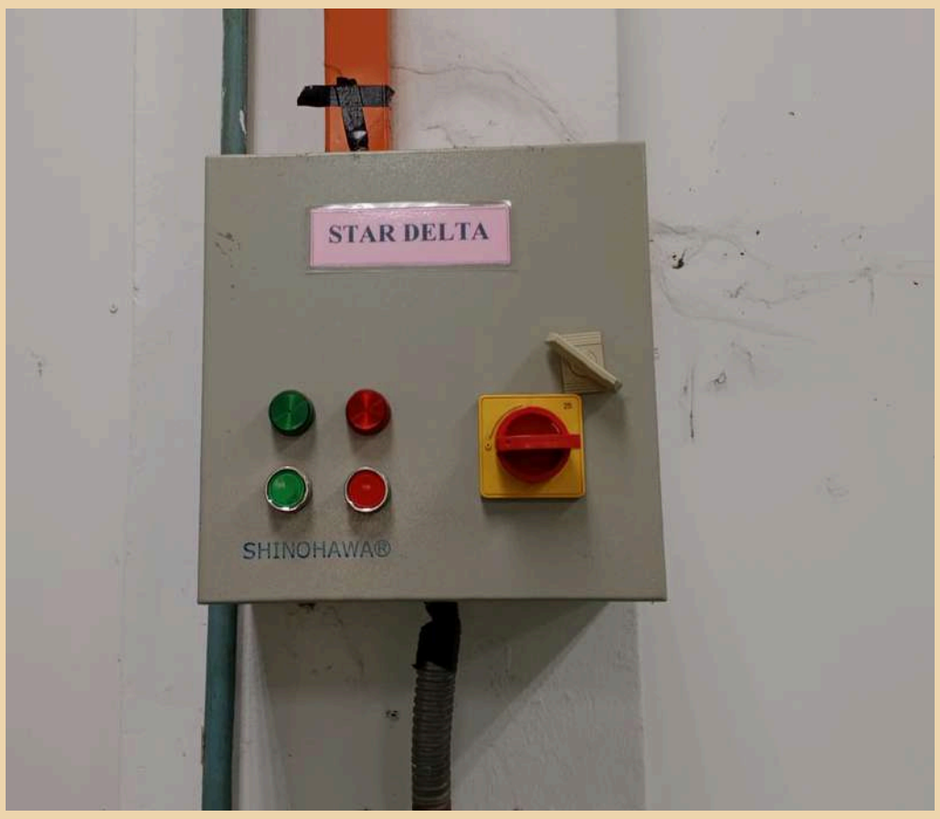
3. Ensure that the compressor outlet valve is **fully open** to allow proper airflow.



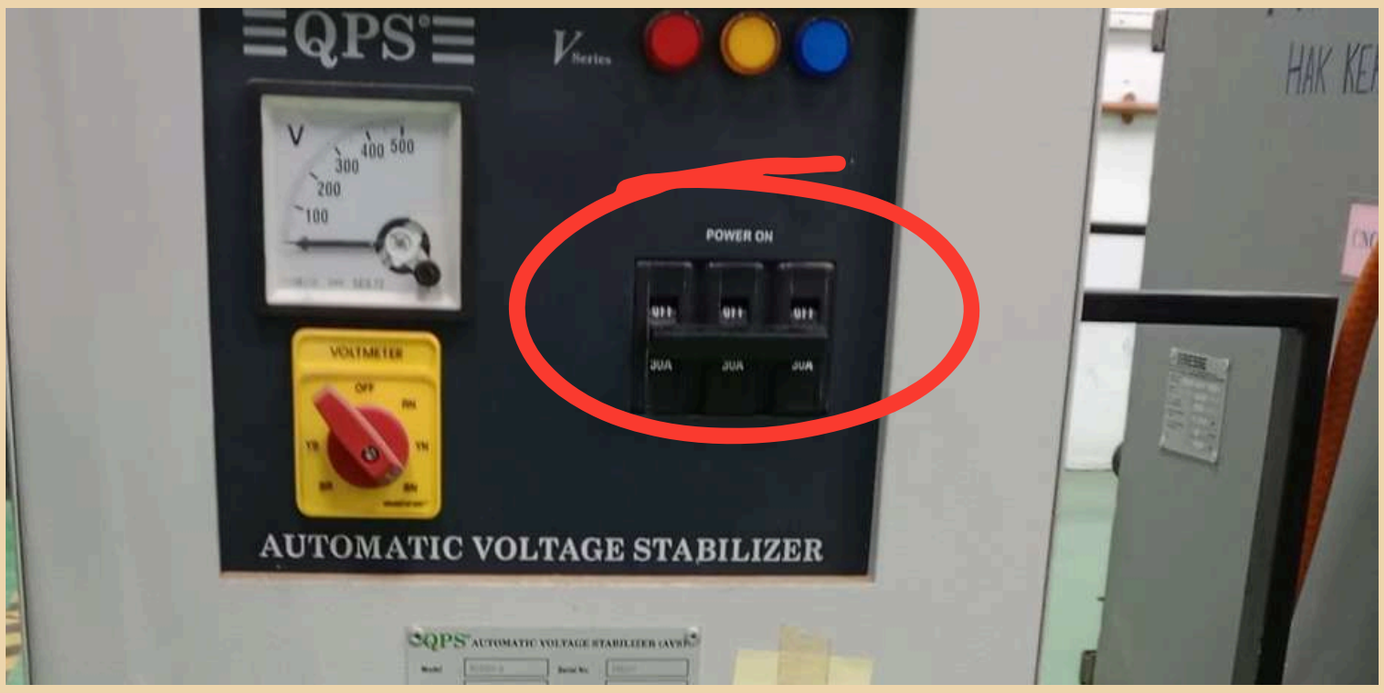
4. Turn on the dryer and **make sure** that the moisture meter indicator is positioned within the **blue** range.

5. Push the run button and wait for at least **10 seconds** to reach the desired pressure level.

6. Push the green button **on** star delta and make sure **release** the valve.

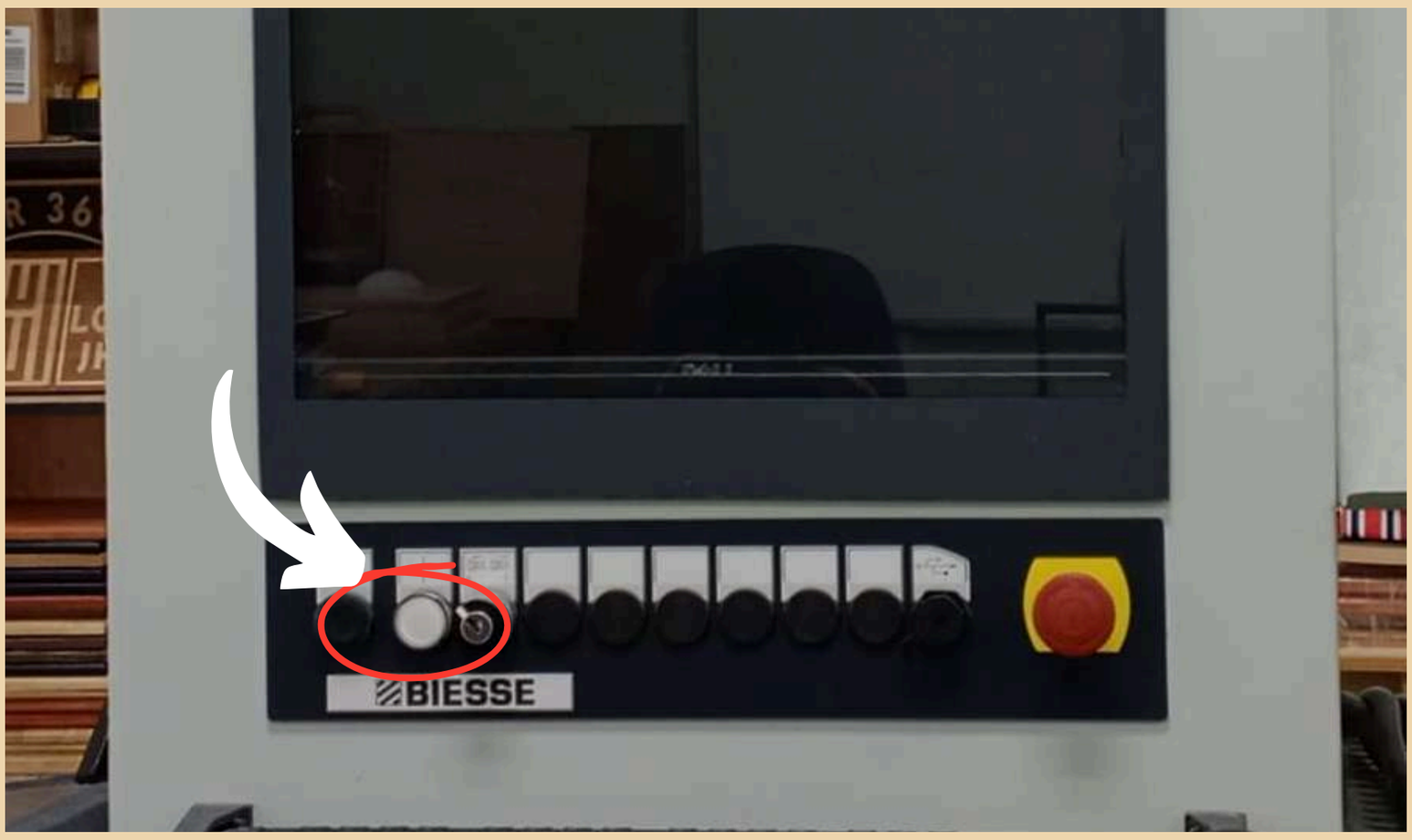


7. Pull the switch **on** the Waltz stabilizer

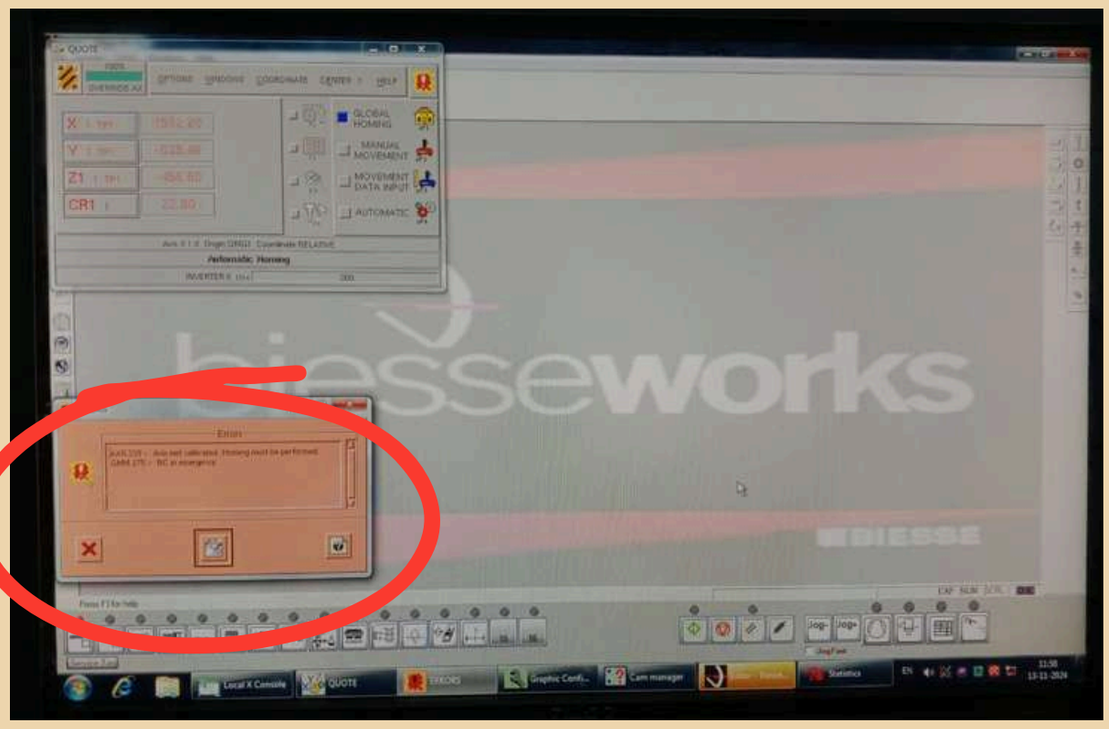


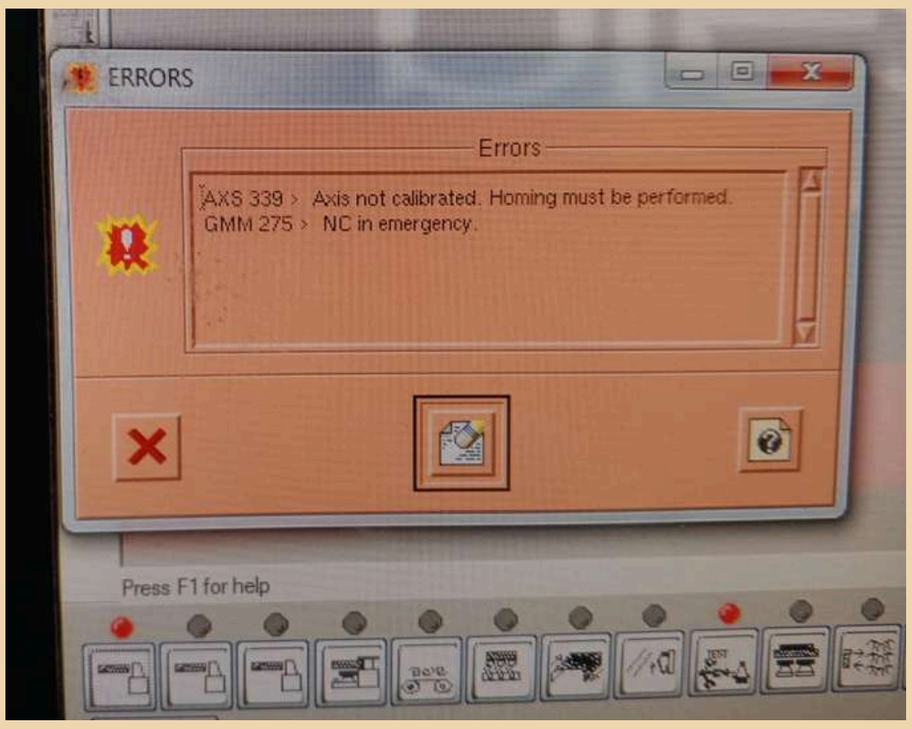
8. Open the control panel and power **on** the PC. Then , turn **on** back-up battery

9. Press the white power button

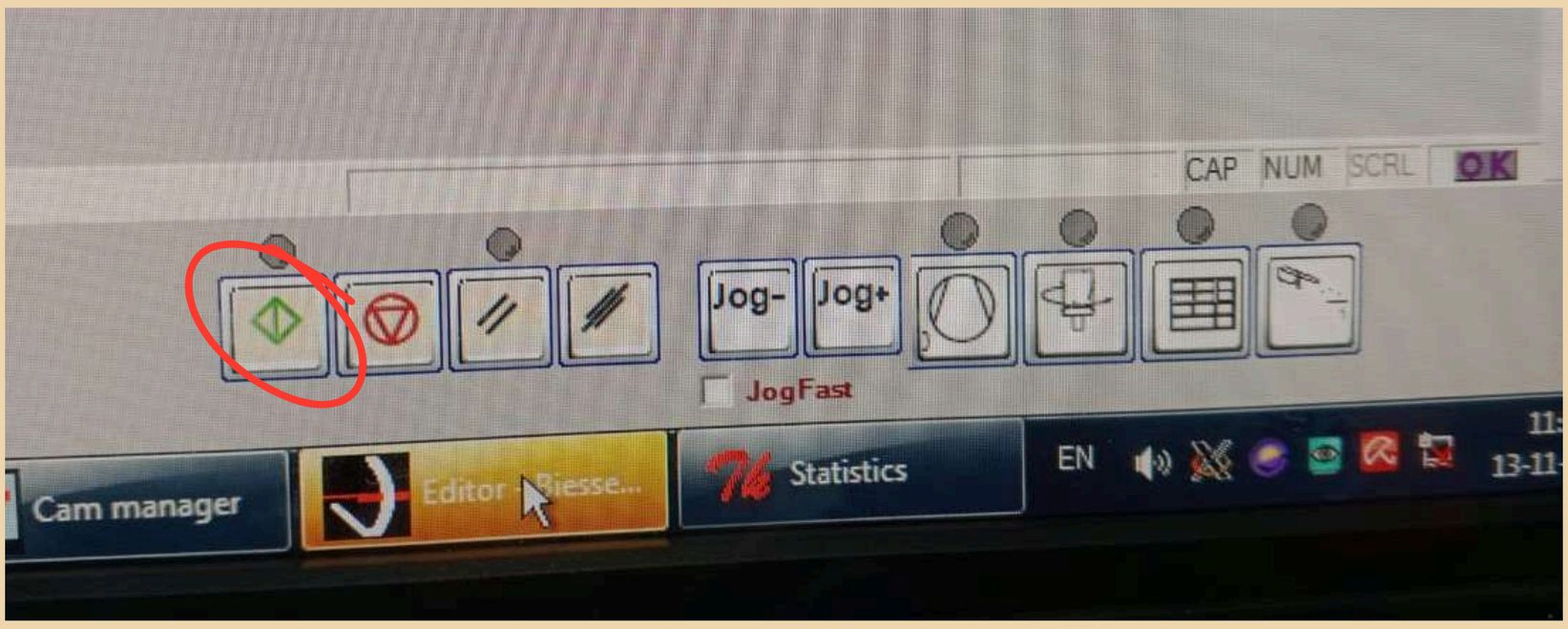


10. To clear the error, press the reset button and wait for the system to refresh.





11. Start the homing process to align the machine to its home position.



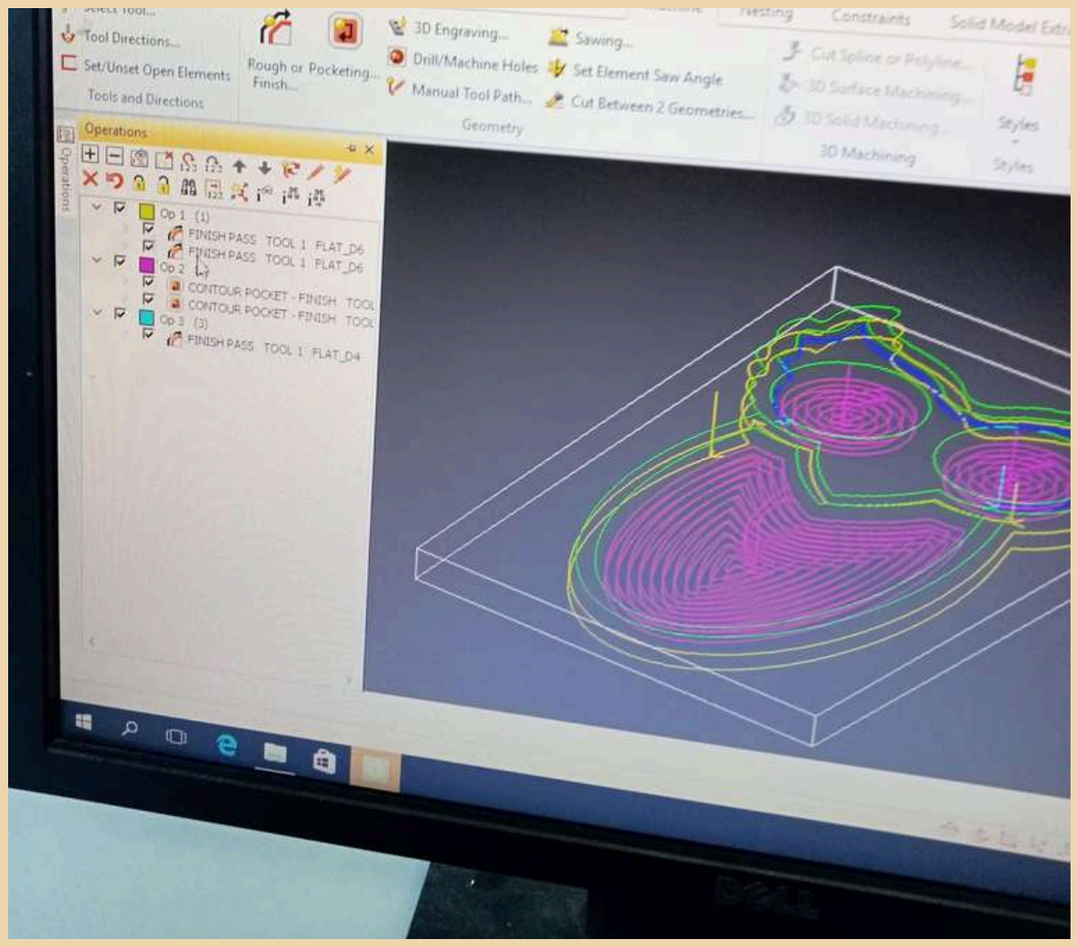
To start, **double-click** the icon.

12. Start the **cone test** to check the tool holder in the tool magazine.

2. Program Operation / Machining Program

1. Begin with the design in **CAD** or **CAM** software.

References



Draw in Software

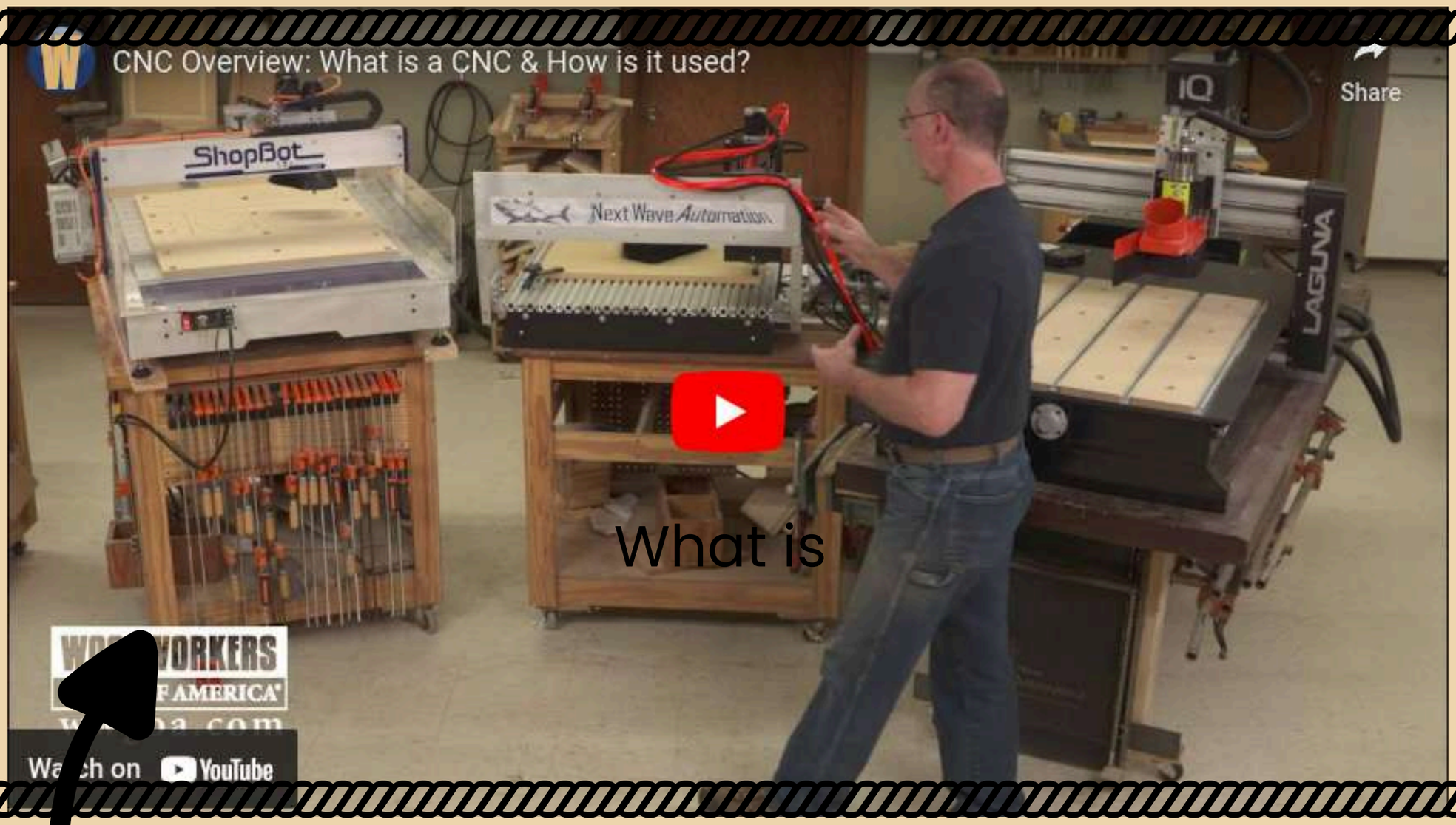
2. Open the file
3. Unload tool command and optimize
4. Save as program file (in software machine)
5. Open table tooling
6. Setting the monitor , worktable parameter , optimize then save and return to editor
7. Optimize and save then add program to job list .
8. Confirming program and check the window code.
9. Run the dust extraction system
10. Click start button twice , after that, press green button on control tower
11. Set up the material on the suction cup , press the vacuum padle to activate vacuum power on suction cup
12. Execute program by pressing the green button at control tower
13. Machine running . After the machine progression are done , take the material and on monitor , click stop , reset and clear icon

CHAPTER 5 :

Video

Video

What is a CNC & How is it used?



Click Here

OR

Tap to play or you can click the link

CHAPTER 6 :

Conclusions

CONCLUSIONS

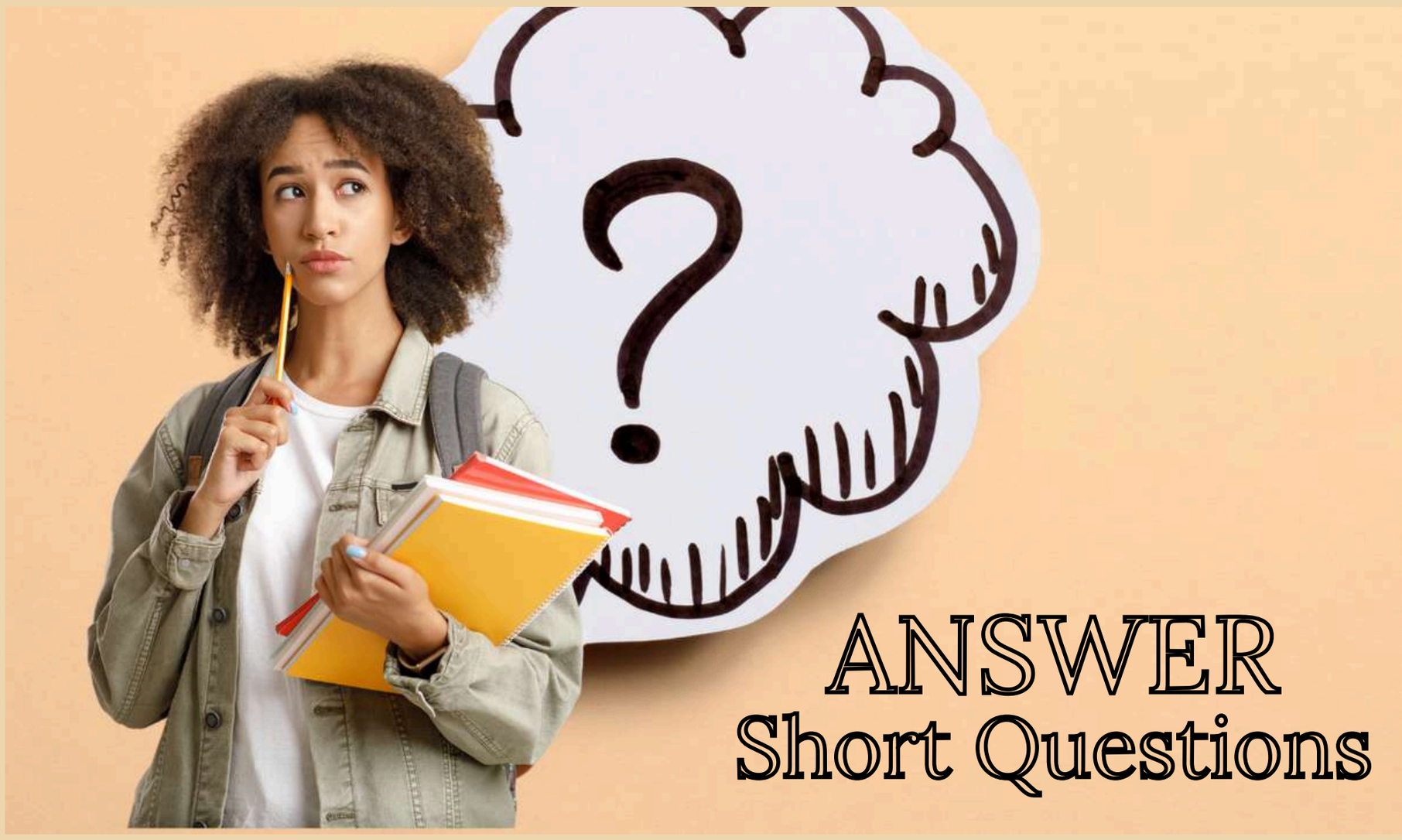
- CNC wood machines represent a major advancement in woodworking, offering precision and efficiency that streamline the production of intricate designs. These machines enable the creation of complex patterns and shapes with remarkable accuracy, transforming ideas from design software into tangible products. By automating much of the cutting and shaping process, CNC wood machines improve both consistency and production speed, making them valuable for both custom projects and large-scale manufacturing.

- The integration of CAD and CAM software allows users to transition smoothly from design to production, with the flexibility to adjust or modify projects as needed. In terms of safety, CNC machines offer an advantage by reducing direct human interaction with cutting tools, though proper safety measures remain essential. Over time, while CNC wood machines may require a high initial investment, they offer cost savings by minimizing material waste, speeding up production, and lowering labor expenses. Additionally, these machines can contribute to more sustainable practices by maximizing material usage and minimizing waste, especially with efficient planning.

- Overall, CNC wood machines bring a blend of creativity, automation, and sustainability to modern woodworking, making them indispensable tools for today's woodworkers seeking precision, versatility, and efficiency.

CHAPTER 7 :

Short Question



You are required to answer these questions and discuss the answers in the class.

NO.	QUESTIONS
Q1	Which type of tool is commonly used in a CNC wood machine to cut wood?
Q2	In CNC machining, what software is typically used to create designs and control the machine?
Q3	Which axis movements are generally involved in a standard CNC wood machine?
Q4	What is the purpose of the "**home**" position in CNC machining?
Q5	What does G-code refer to in CNC machining?
Q6	What is a common safety feature on CNC wood machines to protect operators?

"Success is not the key to happiness. Happiness is the key to success. If you love what you are doing, you will be successful."

– Albert Schweitzer

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