

Lab Safety Training

Before operating the CNC machine, it was crucial to complete a safety training session. The CNC milling machine is a powerful tool, and improper use can lead to injuries, tool breakage, or material damage.

Key Safety Considerations

Personal Protective Equipment (PPE)

- Safety glasses: Protect against flying debris.
- Hearing protection: CNC machines can be loud.
- No loose clothing, jewelry, or gloves: These can get caught in moving parts.
- Closed-toe shoes: Protect feet from falling tools or materials.



Emergency Stop and Safety Protocols

- The Emergency Stop (E-Stop) button immediately halts all operations.
- Power failures or sudden machine malfunctions require a manual reset before resuming operations.
- Fire hazards exist when cutting flammable materials, so a fire extinguisher must always be within reach.
- A first aid kit should be easily accessible in case of minor injuries.



CNC Machine Overview & Controls

For this assignment, we used the Fresadora CNC 1325, a mid-size CNC router equipped with an air-cooled 4.5 kW spindle, a vacuum bed.

Machine Components The main components of the CNC router include:

- Spindle: The motorized cutting tool, capable of reaching 18,000 RPM.
- Worktable: The machine features a vacuum table that helps secure materials during cutting.
- Linear Motion System: The X and Y axes move using a rack-and-pinion system, while the Z-axis is controlled via a ball screw drive.
- Control System: The DSP handheld controller allows the operator to move the spindle and set the zero position manually.



Setting the Home Position we must set the home position (machine zero):



- Move the spindle to the desired origin point (X, Y, Z).
- Use the DSP controller's movement keys to fine-tune the positioning
 - Set this point as the zero reference by pressing "XYZ Zero".
- Control System: The DSP handheld controller allows the operator to move the spindle and set the zero position manually.

Router bit



The choice of router bit determines the cutting efficiency and final surface quality.

- **Spiral Upcut Bit:** This bit is great for removing material quickly and keeping the cut cool. It pulls the chips upward, which helps clear debris but can also cause rough edges on the top surface. It works best for plastics, soft metals, and deep cuts, where chip evacuation is important.
- **Spiral Downcut Bit:** Unlike the upcut bit, the downcut bit pushes chips downward, leaving a cleaner top surface. This is ideal for wood, plywood, and laminates, where you want smooth edges on the visible side. However, it can trap chips in deeper cuts, which might generate heat and affect performance.
- **Straight Bit:** A straight bit cuts evenly in all directions, making it perfect for pocketing and simple profile cuts. It doesn't create a pulling effect like spiral bits, which helps prevent material tear-out. This bit works well for MDF, softwood, and plastics when a clean and stable cut is needed.
- **Compression Bit:** A combination of upcut and downcut geometry, this bit is ideal for plywood and veneer materials. It pulls up from the bottom and pushes down from the top, leaving both surfaces clean and smooth. This makes it perfect for materials that tend to chip or splinter. Each of these bits has its own strengths, and selecting the right one depends on the material, the type of cut, and the final finish you want. By understanding their behavior, we can achieve cleaner cuts, faster production, and better overall results in our CNC projects.
- **End Mill:** Designed for precision and high accuracy, end mills are commonly used in metal, acrylic, and composite materials. They provide smooth, controlled cuts and are great for detailed profiles and deep slots. Unlike typical wood-cutting bits, end mills have sharper edges and can handle harder materials.



Image Source:
ToolsToday Learning
Desk

Vacuum Table & Sacrificial Board

Why Material Holding Matters? Before any CNC machining operation, one of the most critical steps is securing the material. If the workpiece moves, even slightly, during the cutting process, it can cause misalignment, rough edges, tool breakage, or even machine damage. To ensure stability, two common methods are used: vacuum hold-down systems and sacrificial boards.



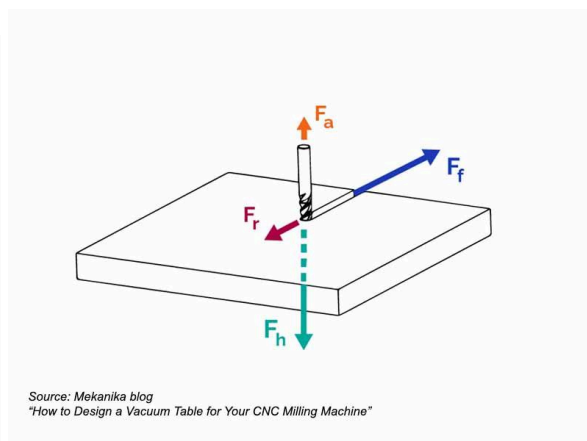
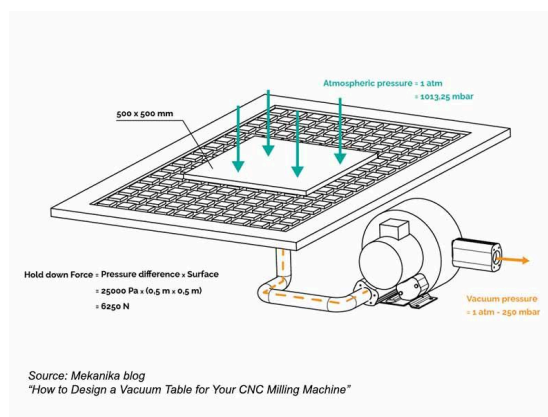
How the Vacuum Table Works

A vacuum table uses negative pressure to hold down the material during machining. The principle behind it is simple: atmospheric pressure pushes down on the material while the vacuum pump removes air from beneath it, creating a pressure difference that keeps the workpiece firmly in place.

How Strong is the Hold?

The force holding the material depends on the vacuum pressure and the surface area of the material. A larger material has more surface area in contact with the vacuum, increasing the holding force.

See the diagram below for a visual explanation of how vacuum tables generate hold-down force
See the diagram below for an illustration of cutting forces acting on the material



Source: [Mekanika.io](https://mekanika.io)



The CNC router we worked with has a vacuum table divided into six independent sections, controlled by valves. Each section can be activated or deactivated depending on the size and position of the material being cut. By closing certain valves and keeping only the necessary sections open, we could optimize the suction force applied to the board, making sure it stayed completely flat against the sacrificial board.

Factors Affecting Vacuum Strength:

- Material surface area Larger pieces experience stronger suction.
- Leaks or gaps in material Air leaks reduce the vacuum's effectiveness, so materials with holes or rough surfaces may need additional sealing
- Vacuum pump power A higher-pressure vacuum pump creates a stronger hold.

Sacrificial Board

The Role of the Sacrificial Board A sacrificial board is a layer of material placed between the CNC machine's bed and the workpiece. Its main purpose is to protect the CNC table from tool damage while also improving vacuum performance.

- **Protecting the CNC Table:** Since CNC operations often involve cutting all the way through the material, the bit can cut slightly into the machine's surface. A sacrificial board absorbs these cuts, preventing permanent damage to the actual bed.
- **Enhancing Vacuum Hold** Some materials, like plywood, have tiny air gaps that weaken the vacuum suction. A sacrificial board—typically MDF—creates a better seal between the vacuum table and the material, preventing air leaks and ensuring a stronger hold.
- **Allowing Full-Depth Cuts Without Worry** With a sacrificial board in place, users can confidently set their toolpaths to cut slightly beyond the actual material thickness, ensuring clean cuts without worrying about damaging the machine

