

EDU[**CAD**]TION **STUDY GUIDE**

How to Design for Different Machines

Chapter 3, Lesson 4

SendCutSend

Material + Machines = Reality

- In previous lessons, we learned that **Material + Machines = Reality**.
- The materials you choose determine what can be cut, but the machines define how it can be cut.
- Every machine operates within an X, Y, Z coordinate system, which determines its level of control and the dimensional complexity it can achieve. In this lesson, we'll explore how a machine's capabilities can directly influence and constrain your design.

Machine Categories

- Machines are typically classified by the number of axes they can move in:
- **2-Axis Machines:** Move only in the X and Y directions.
- **3-Axis Machines:** Add Z-axis motion (vertical movement).
- **3+ (Multi-Axis) Machines:** Include rotational axes, allowing for tilting, turning, and complex part geometries.

1. Two-Axis Machines

- Two-axis machines move in a flat, planar motion, cutting along X and Y only. They cannot perform partial-depth cuts or vertical contouring.

Examples:

- **12K Fiber Laser:** Cuts conductive materials like metals. Operates with X and Y motion and minor Z adjustment for material thickness.
- **CO2 Laser:** Similar setup, used for non-conductive materials such as plastics and woods. **Note:** *some plastics can emit toxic fumes when cut*
- **Water Jet:** Uses high-pressure water mixed with garnet to cut composites like G10, carbon fiber, and phenolics.
- **Tube Laser:** Appears 3D, but functionally operates in two axes, rotating and translating tubes along their length.

2. Three-Axis Machines

- Three-axis machines add vertical movement (Z-axis) to the X and Y motion, allowing for 3D operations such as pocketing and engraving.

Example: **CNC Routers**

- Move in X, Y, and Z directions, enabling precise cuts and engravings.
- Feature a gantry-style frame, which allows the spindle (cutting head) to move around the material.
- Equipped with a vacuum table for workholding, eliminating the need for clamps and simplifying material changes.
- Ideal for cutting large sheets like 4×8 plywood while maintaining accuracy and speed.

3. Three-Plus (Multi-Axis) Machines

- **Three-plus-axis** or **five-axis machines** add rotational axes (A and B) to the standard X, Y, Z setup, allowing the tool or part to rotate.

Example: **5-Axis CNC Mills**

- Can tilt and rotate the part, machining multiple faces without repositioning.
- Allows for intricate and curved geometries in a single setup.
- Equipped with automatic tool changers and pallet systems for continuous, unattended operation.
- Used for high-precision, multi-surface parts in advanced manufacturing applications

Design Implications

- Machine capability dictates what geometries are possible and how efficiently parts can be made:
- **2-Axis:** Great for flat 2D parts; cannot produce partial-depth or 3D features.
- **3-Axis:** Enables pocketing, engraving, and contouring; good for most 3D parts.
- **5-Axis:** Allows for the highest geometric complexity; ideal for organic shapes or components requiring multiple angled surfaces.
- Designers must also consider the **machine envelope** (the maximum size of part that can be cut).

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Summary

Understanding the machines used to produce your designs ensures they are manufacturable and efficient. Knowing which machine suits your material and geometry helps reduce production time, costs, and complexity, turning CAD concepts into real, tangible parts.

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