Computer Numeric Control (CNC) Machine Operation

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ENT 4499 - Culmination

Introduction

Welcome to the world of learning CNC operation. CNC stands for Computer Numeric Control. CNC machines are automated, computer programmed cutting machines. CNC machines can cut through metal, wood, plastics, foam and other materials. Because of their precision and speed they are widely used in the entertainment industry.

My goal this semester was to see how much I could learn about CNC including familiarizing myself with various Computer Aided Machining (CAM) softwares. I drafted projects, conducted interviews, read books and spent a week at Showman Fabricators shadowing operators.

CNC History

- *1949-1953* US Government contracts The Parsons Corp and MIT to develop the first NC system

- *1953* The Cincinnati Tool Co. converts a milling machine into a 3-Axis (X,Y,Z) automatic mill driven by a servo motor.

- *1956* Alfred Herbert Ltd develops the first NC tool path operated control system in the UK

- *1960-1970* Revolutionary advances make CNC reality. Geometries are controlled and changed by programs. Development and lead time is reduced. Manufacturing small batches and "one-offs" becomes profitable.

- *2015-Future* CNC machines have become an essential part of manufacturing industries and are more available and affordable than ever. DIY kits allow individuals to have one in their home.

Basic CNC Machine Anatomy

CNC machines come in different sizes and configurations. However most machines share the same basic parts and mechanics.
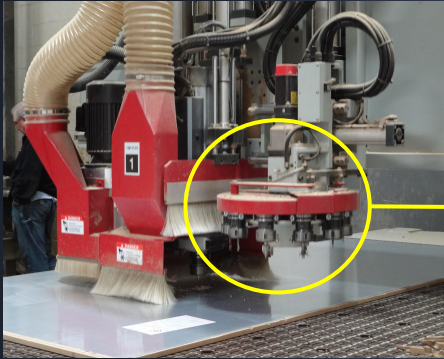
|	
1.	Bed
2.	Gantry (X and Y axis)
3.	Gantry Track and Guide Rail
4.	Tool
5.	Spindle & Spindle Motor
6.	Servo Motor
7.	E-Stop
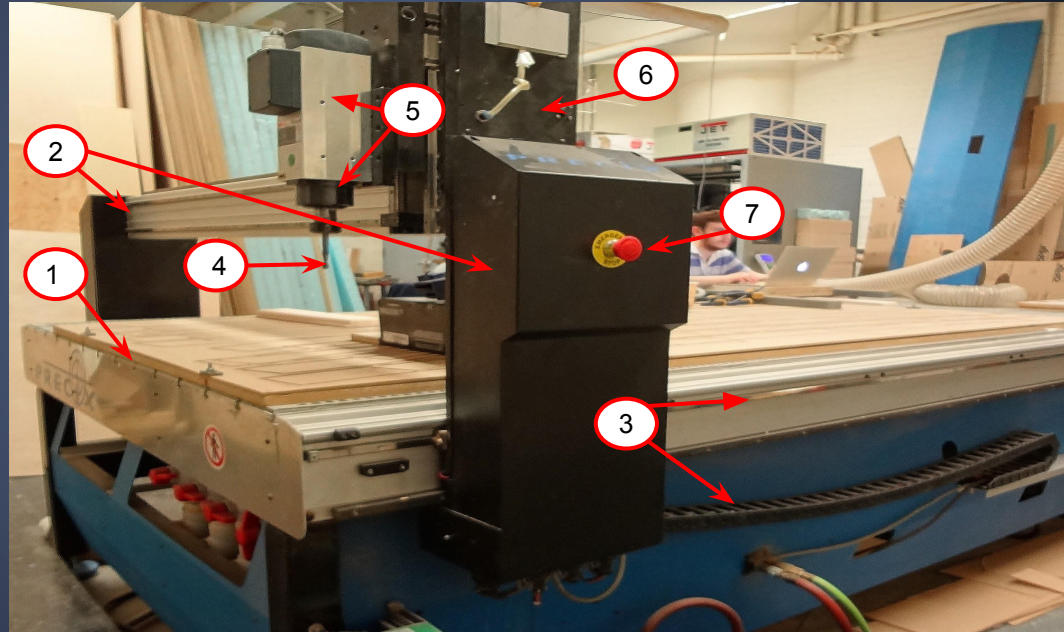
The Precix 1110 3-Axis Milled used at NYCCT.
Specs: 5'X10' bed, 18000rpm spindle, Single tool.

Basic CNC Machine Anatomy - continued

CNC machines also come with automatic tool changers. Most professional shops will have this feature.

When using a single tool machine you have to manually swap out tools which is much like swapping router bits on a hand router. The machine also stops, returns to the origin point and the program has to be restarted. The automatic tool changer saves time by switching tools in a matter of seconds in it's current position and continues cutting on it's own.
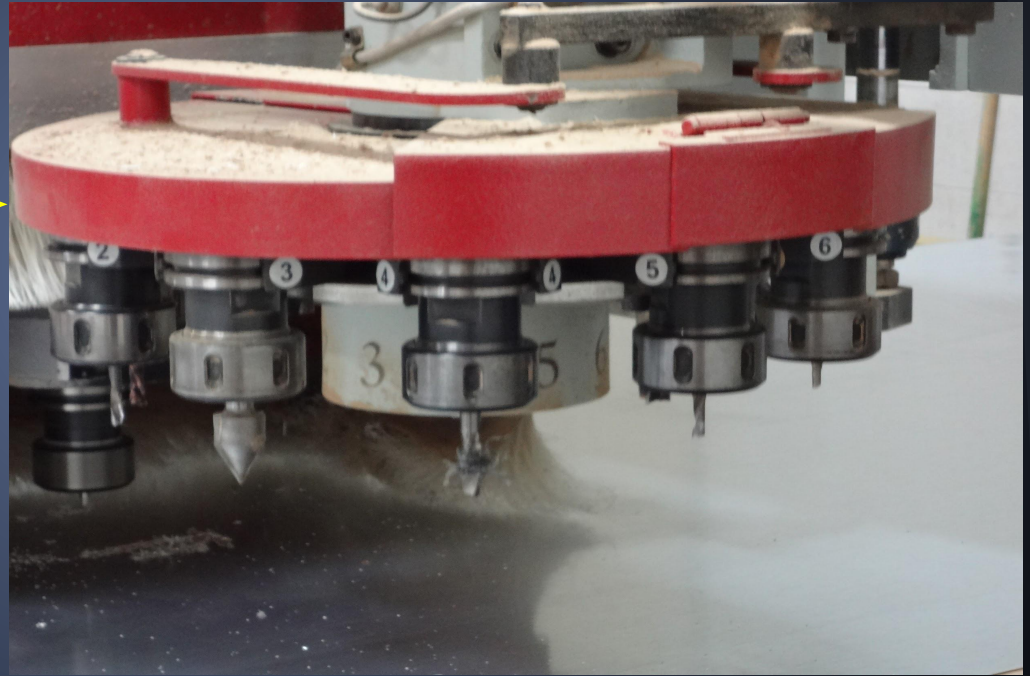
The Anderson Stratos/ Pro 24' used by Showman Fabricators.
*Specs:* 6'x24' Bed, 15HP/24000RPM spindle, 10 tool automatic changer.

Concept

Basic CNC machines work based on the Cartesian coordinate system (3 - axis (X,Y,Z) planes). The material is is usually laid on the bed of the machine and secured by suction. Below is a brief explanation of how a CNC Machine moves to cut a shape.
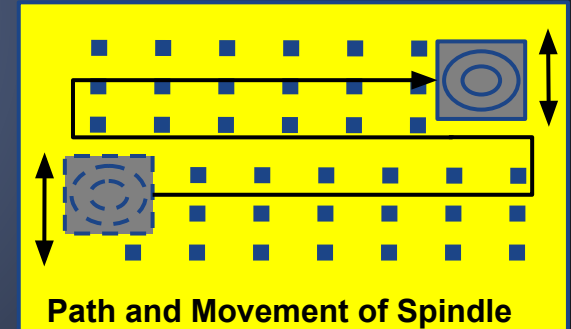
Z-Axis
(Profile View)

X, Y Axis
(Top View)

X

Y

X, Y Travel, Z Axis Cutting
(Top View)

Path and Movement of Spindle
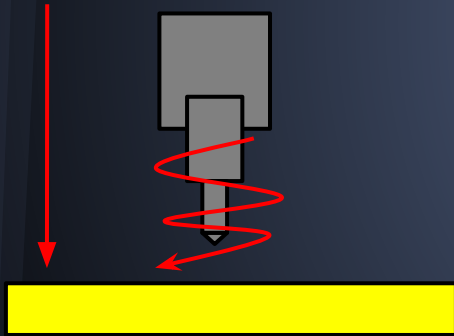
A) The spindle spins the tool as it plunges down into the material on the Z axis
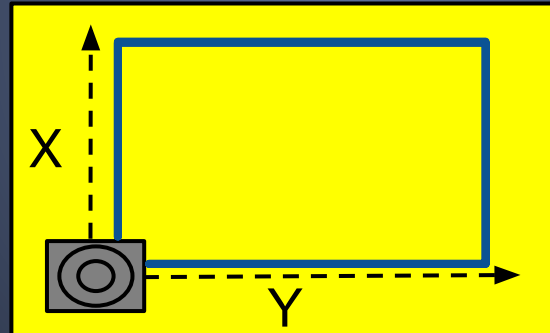
B) To cut this shape, the tool path may begin its travel on either the X or Y axis depending on the "G" Code.

C) In this case the machine moves in the X,Y axis while drilling holes in the Z axis

Mechanics

CNC machines work by moving and cutting in 3 - axis (X,Y,Z) planes. The Gantry is the heart of the movement. Smaller machines run with only one motor for all 3- axis while heavy duty machines have a dedicated motor for the each axis.

The Onsrud 145G18A used at Scenic Corp
Specs: 5' X12' Bed, 18HP/18000RPM Spindle, 12 tool automatic changer.

The X and Y axis have a mechanism moves with a precision ground ball screw and ball nut.
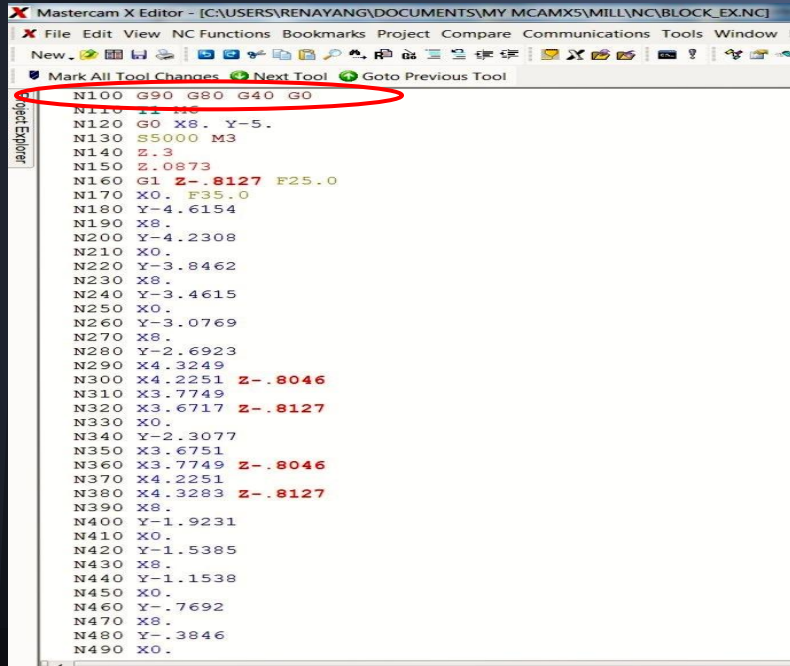
The screw moves along the railing on the side in each axis. Think of the ball nut as a nut with ball bearings for threads
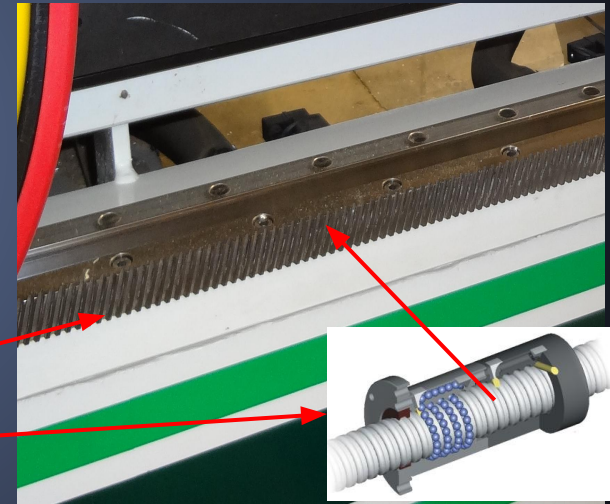
precision ground ball screw

The "G" Code

The "G" code is what makes CNC machines run. The code gives the machine the instructions on what tools it needs, speeds and the tool path to run. CAM software generates the G code which is then transferred into the machine control center.

Common G - Code commands

G90 - Absolute Mode

G80 - Cancel Canned Cycles

G40 - Cancel Cutter Compensation

G0 - Move in Rapid Mode

N100 is the number of the line of code. It's always a good idea to see how many lines of code you have generated as some machines have a limited number of lines they can process at one time and will require that you break up the code into "different jobs".

The "G" Code - Continued

Brief Example of a functioning Code

```
%
T2 M6
S1400 M03
G0 G54 X0 Y0
G43 H1 Z1.
X - 1.625 Y -.625
%
```

Explaining The Code

% in some machines it is used to mark the start and end of the program

T2 is # of the tool to be installed **M6** installs the tool

S1400 is the spindle speed (1,400RPM) **M03** turns on the spindle

G0 sets the machine to move in rapid mode (100% of a defined speed in inches per minute, i.e 400 in/min)

G54 sets the absolute starting point. **X0 Y0** in this case it is 0 on the X-Axis and 0 on the X-Axis. (this may be defined anywhere on the material being cut)

G43 picks up a tool to the offset length **H1** defines offset length (.001mm) **Z1.** Raises the tool in the Z-Axis by 1 inch in rapid mode

The "G" Code - Continued

Pictured above are the computers that control the CNC machine and WaterJet at Showman Fabricators. At their facility the computers are networked and the G-Code file is simply transferred from one folder to another. However the machines can only be operated from their control station.

Data Chain

```
┌─────────┐        ┌─────────┐        ┌─────────┐
│   CAD   │───────▶│   DXF   │───────▶│   CAM   │
└─────────┘        └─────────┘        └─────────┘
```
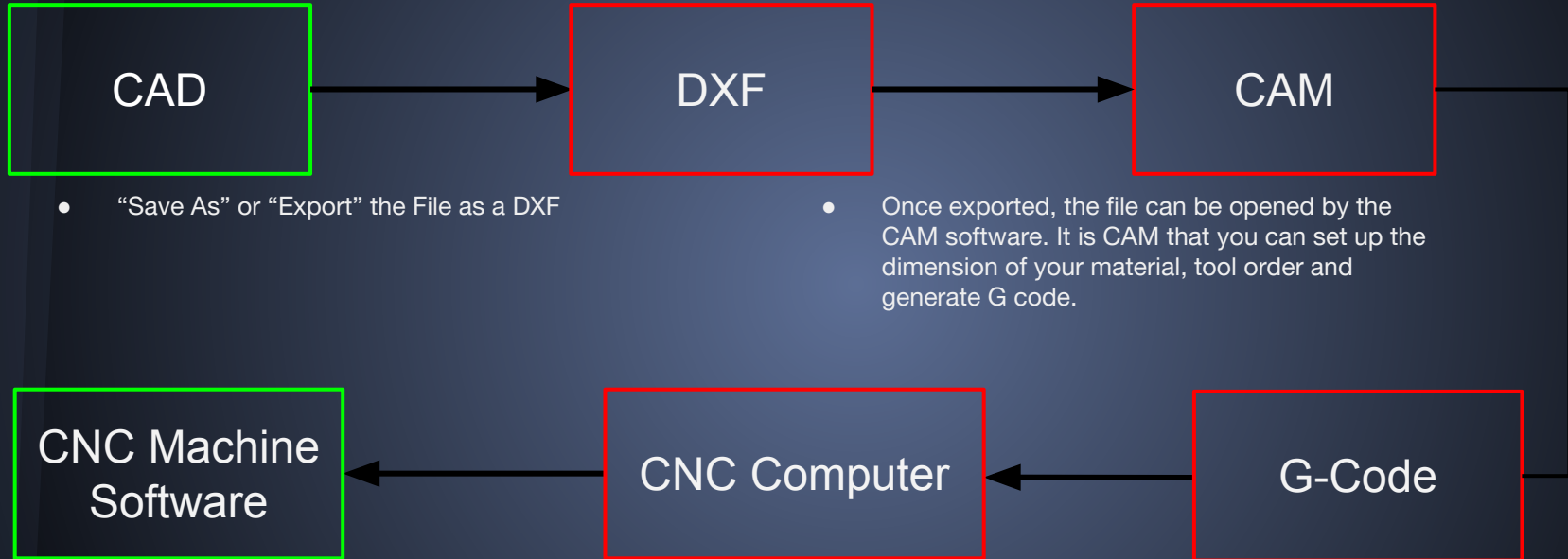
- "Save As" or "Export" the File as a DXF

- Once exported, the file can be opened by the CAM software. It is CAM that you can set up the dimension of your material, tool order and generate G code.

```
┌──────────────┐   ┌──────────────┐   ┌──────────────┐
│ CNC Machine  │◀──│ CNC Computer │◀──│   G-Code     │
│  Software    │   └──────────────┘   └──────────────┘
└──────────────┘
```

- The G-Code is loaded into the CNC machine's proprietary software and runs the program

- The G-Code is transferred into a folder which the CNC's computer can access. The code is sometimes generated as a .txt file.

Computer Aided Machine (CAM) Software

One of the challenges in training as a CNC operator is learning various types of CAM software. At Showman Fabricators they use Sigmanest, Enroute, OMAX Layout (WaterJet). While at Scenic Corp and NYCCT Architecture uses RhinoCAM. However, NYCCT Engineering uses MasterCAM. In addition you must also familiarize yourself with the software used to actually operate the machine

Tooling

CNC machines can be thought of as big fancy computerized routers. In order to get the product you want you must choose the right tool. Like materials, tools also come in different shapes and sizes. In addition some are more robust than others.

Tooling - continued

Tools come in different types for different jobs. In the entertainment industry realized that some bits are de facto standards for almost every job. The type of material, thickness and hardness are things to consider when choosing the tool(s) for the Job. The tool that you use will help decide on your settings for spindle speed, plunge rate, and feed rate

Most Commonly used bits:

Upcut Spiral O Flute

Chipbreaker bits

Compression Bit (Carbide Coated)

Engraving Bits

Settings to Consider for tool and Material being cut

- Spindle Speed (SS)
- Plunge Rate (PR)
- Feed Rate (FR)

SS measured in RPM - Rotations Per minute

PR and FR measured in IPM - Inches Per Minute

Tooling - continued

Tool Properties and Descriptions

<u>Single Flute - Upcut Spiral O Flute</u>

This tool is mainly used to cut plexiglass. The upcut feature pushes the chips up so that they don't weld back into the piece being cut.

Material: 1 ½" Plexiglass
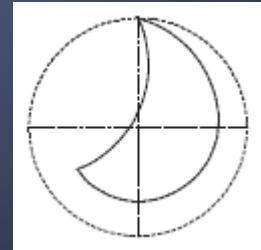
Machine: Stratos/Pro 24'

Tool Width : ½"

Settings:
SS: 18,000 RPM
PR: 450 IPM
FR: 500 IPM

Single Flute
Bottom view
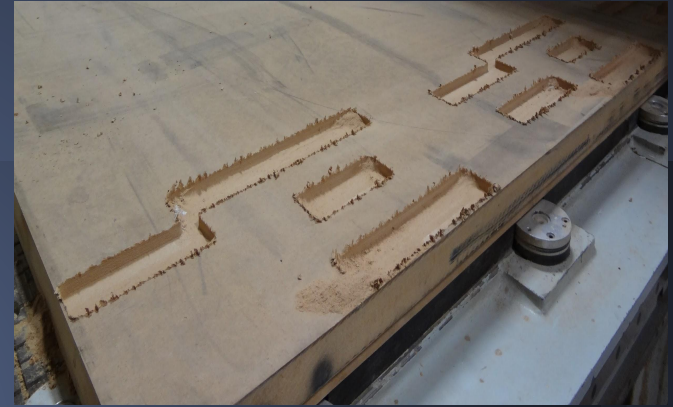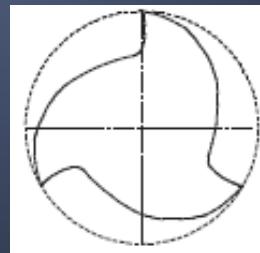
Tooling - continued

Tool Properties and Descriptions

<u>Chip-Breaker/Hogger</u>

This tool is mainly used to cut deep into hard or very thick materials. The spike like extrusions give a rough edge to the cut but it does the job quickly. A finer tool is usually used to go over the area to smooth out the cut

Material: 1 ½" MDF

Machine: Stratos/Pro 24'

Tool Width : ¾"

Settings:
SS: 18,000 RPM
PR: 500 IPM
FR: 600 IPM

3 Flute Bottom view
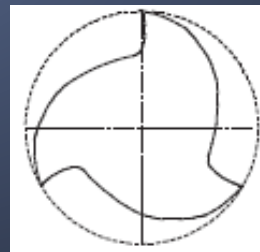
Tooling - continued

Tool Properties and Descriptions

<u>Compression Bit</u>

This tool is the most widely used bit in entertainment fabrication shops (about 60% for Scenic Corp). The tool has spirals in 2 different directions. This gives clean finish on both sides when cutting through veneer and composite materials. The spirals also help move chips out of the tool path

Material: ½" MDO

Tool Width : ⅜ "

Machine: Stratos/Pro 24'

Settings:

SS: 18,000 RPM
PR: 300 IPM
FR: 200 IPM

3 Flute Bottom view

Tooling - continued

Tool Properties and Descriptions

Engraving Bits

These tools are used to do exactly what the name says. I found that when engraving is not critical most operators will use whatever tool is first to cut and set the depth of the cut to about 1/8"- 3/16".

Carbide Tip Engraving Bit

¼" V-Groove Aluminum

Material: ½" Plexi

Tool: ¼" V-Cut Aluminum bit

Machine: Roland MDX-540

Settings:
SS: 800 RPM
PR: 40 IPM
FR: 50 IPM

What can we make with CNC Machines?

- A Detailed Brick Wall

- Signs

- Cool Furniture

Things I did make