TRINITY-AREA
SCHOOL DISTRICT

FABLab

HIGH SCHOOL CURRICULUM

2023

Washington, Pennsylvania

SECTION 2.3

CNC Machining

Background Narrative

Computer numerical control (CNC) machining consists of highly detailed cuts out of metal pieces for industrial hardware products. These industrial components require precise engineering and timely turnaround. To adhere to these standards, many sectors use CNC machines to create the custom parts they need. These industries require reliable, well-made parts with a high level of precision. Common CNC industrial applications include parts for the aerospace, electronics, and medical industries.

In this section, the students will prepare multiple designs on a CNC milling machine. Students start by learning extensive features in computer-aided manufacturing (CAM software). Once the appropriate tool-paths/g-code are generated, it is up to the students to learn how to setup proper work offsets in order to fully operate a CNC milling machine used in the manufacturing industry.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

- J. The nature and development of technological knowledge and processes are functions of the setting.

STL 2. Core Concepts of Technology

- AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.
- CC. New technologies create new processes

STL 8. Attributes of Design

- H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

I. Design problems are seldom presented in a clearly defined form.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

STL 11. Develop the Abilities to Apply the Design Process

M. Identify the design problem to solve and decide whether or not to address it.

N. Identify criteria and constraints and determine how these will affect the design process.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

O. Operate systems so that they function in the way they were designed.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

PA State Standards:

3.4.C. Technology and Engineering Design

3.4.10.C1. Apply the components of the technological design process.

3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.

3.4.D. Abilities for a Technological World

3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.

3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.

Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.

Design.3 - I can initiate design processes to generate multiple solutions to problems I have framed for multiple stakeholders.

Modeling.1 - I can arrange and manipulate simple geometric elements, 2D shapes, and 3D solids using a variety of technologies.
Modeling.2 - I can construct compound shapes and multi-part components ready for physical production using multiple representations.
Modeling.3 - I can define complex systems with parametric relational modeling using generative, algorithmic, or function representation.

Fabrication.1 - I can follow instructor guided steps that link a software to a machine to produce a simple physical artifact.
Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.
Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab's capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Students will apply the ability to use professional CAM software to make parts.
2. Students will demonstrate the proper setups and offsets to operate a CNC milling machine.
3. Students will create accurate metal parts from a CNC milling machine.

Activities:

- ➢ Students accurately design, setup, and perform CNC operations to create a drink coaster, bottle opener, and toothbrush holder project.

Resources:

- CAD & CAM Software (Fusion 360)
- CNC Milling Machine (Tormach) With ATC, ETS & Passive Probe
- Cutting Tools: Carbide End Mills, Drills, Chamfer Mills, & Spot Drills
- Aluminum: Flats (1”x 4” & 0.75”x 1.75") & Rods (0.5”, 2”, & 3.5” Diameter)
- Taps & Dies:

Assessment

- ➢ Students will be evaluated by instructor/student critiques and rubric.
- ➢ Written quiz follows at the end of this section

Activity

Section 2.3

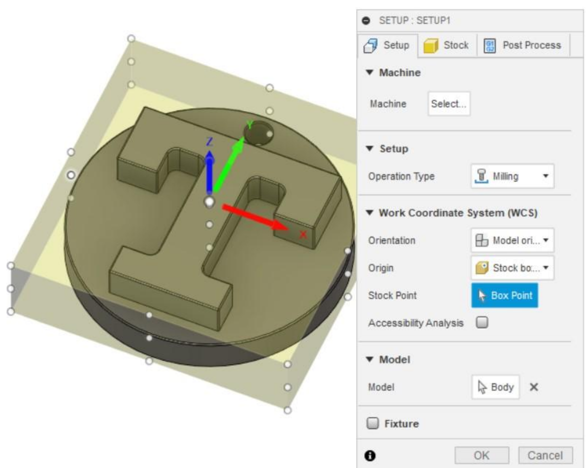
<u>Computer-Aided Manufacturing</u>

Using Fusion 360

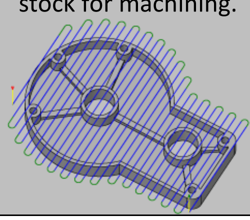
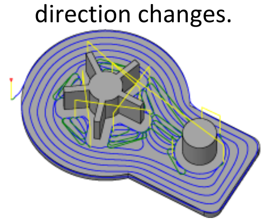
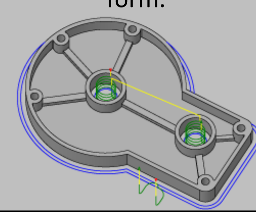
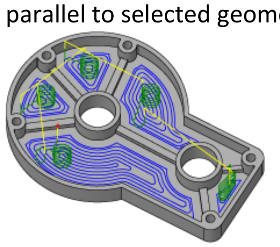
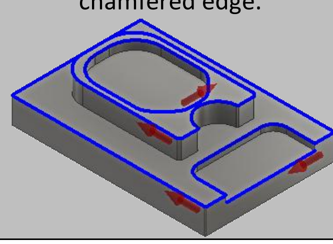
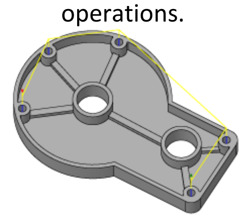
***Start by opening the provided ‘<u>T Medallion.step</u>’ CAD model & importing the <u>‘Trinity HS’</u> tool library.**

Creating a Setup: The setup feature is how you input where everything is located. This includes what you’re machining, the x/y/z direction/location, and the defined stock dimensions.

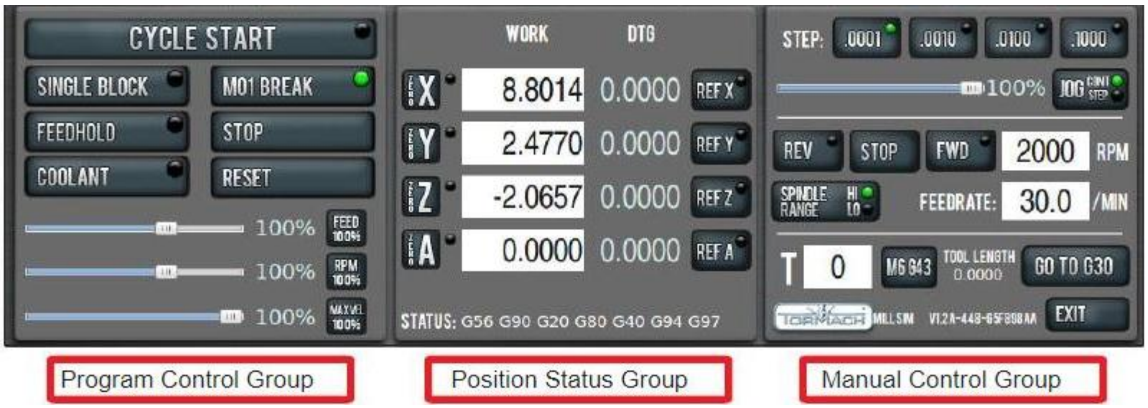
- <u>Setup Tab</u> - Setting the job type and CAD model’s work coordinate system (WSC)
- <u>Stock Tab</u> - Sizing and positioning of the stock in relation to the CAD model
- <u>Post Process Tab</u> - Programming inputs to note in final g-code file



Creating a Tool-Path: Most of the tool-paths for milling/drilling in Fusion 360 consist of five separate setup tabs: Tool, Geometry, Heights, Passes, & Linking. Below are some of the more common tool-path operations that we will be using throughout the course.

Face	Adaptive Clearing	Contour
Removes all material from top of stock to top of model to prepare raw stock for machining. 	Roughing operation that uses a more optimized tool-path that avoids abrupt direction changes. 	Creates a tool-path based on an outline that represents a shape or form. 
Pocket	**Chamfer**	**Drill**
Roughing operation that uses tool-paths parallel to selected geometry. 	Machines along contours creating a chamfered edge. 	Provides access to a wide range of drilling, tapping, & hole making operations. 

CNC Programming/Setup
Using PathPilot



Referencing the Mill
The axes should be referenced before operating the mill to establish soft limits to protect the mill from over travel and to give meaning to work offset values.

Work Coordinate System (WCS)
Also known as the work offset, allows the operator to think in terms of X/Y/Z coordinates with respect to the part, instead of the mill position. Using Tormach's passive probe can touch off the location of your part (often the top face, center of your part or the top left-hand rear corner) and sets the digital readouts (DRO) to zero.

Passive Probe

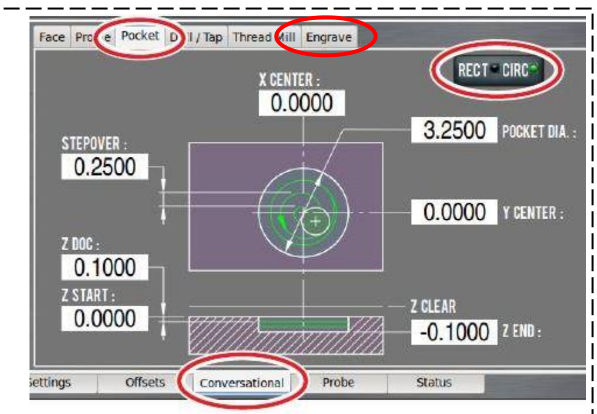
Tool Length Offsets (TLO)
Also known as the tool offset, allows the operator to use tools of different lengths. Using Tormach's electronic tool setter (ETS) can touch off tools automatically to find their offset lengths.

Electronic Tool Setter (ETS)

Create a Metal Coaster
Use conversational programming by creating both a pocket tool-path & engrave tool-path.

<u>Circular Pocket</u>
Tool: 0.375" End Mill
Size: 3" Diameter
Cut Depth: 0.05"

<u>Engraved "T"</u>
Tool: 0.125" End Mill
Size: 2.5" Tall
Cut Depth: 0.05"



Activity

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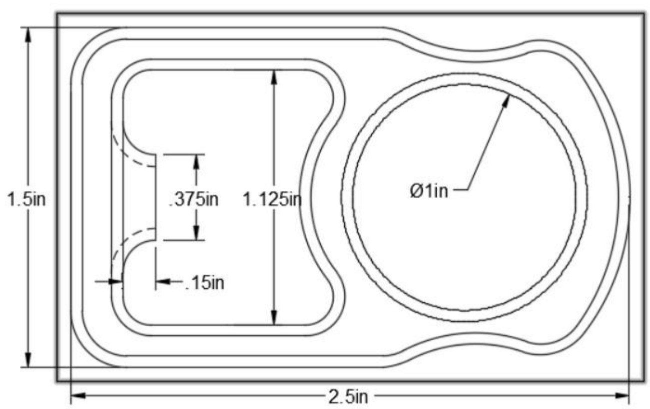
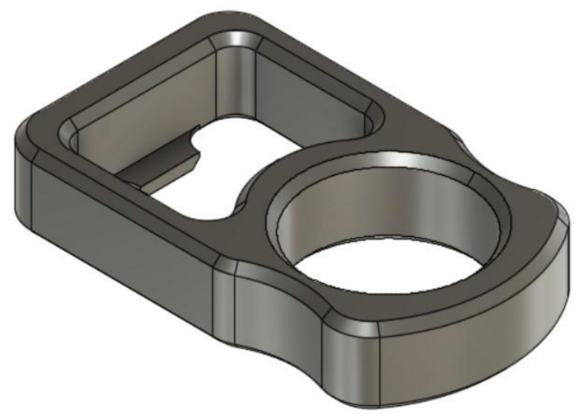
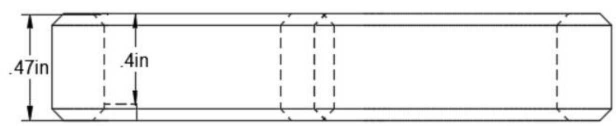
Bottle Opener

Design Challenge







Chamfer All Edges: 0.05"

Rough Stock

0.75”x 1.75" Aluminum Flat

- 2.6” Length

Tool-Paths Required	
(Setup 1)	**(Setup 2)**
• 2D Face • Adaptive or Pocket Clearing • 2D Contour • 2D Chamfer	• 2D Face • 2D Chamfer

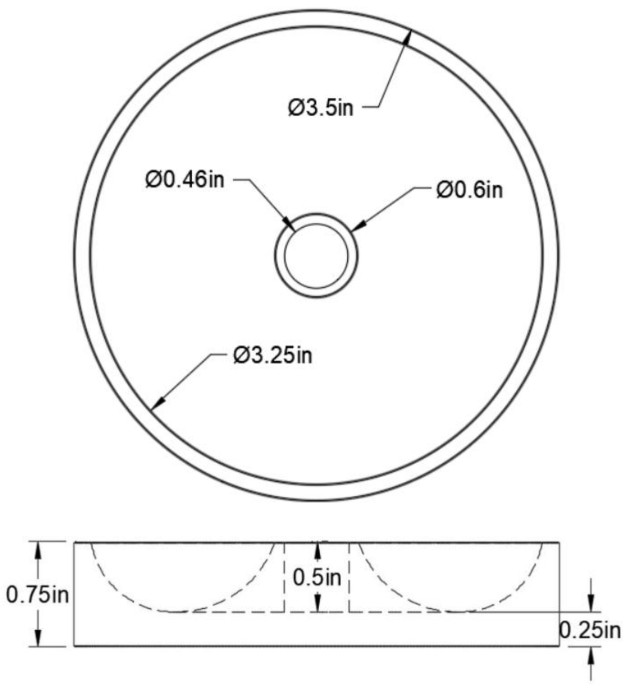
Activity

Section 2.3

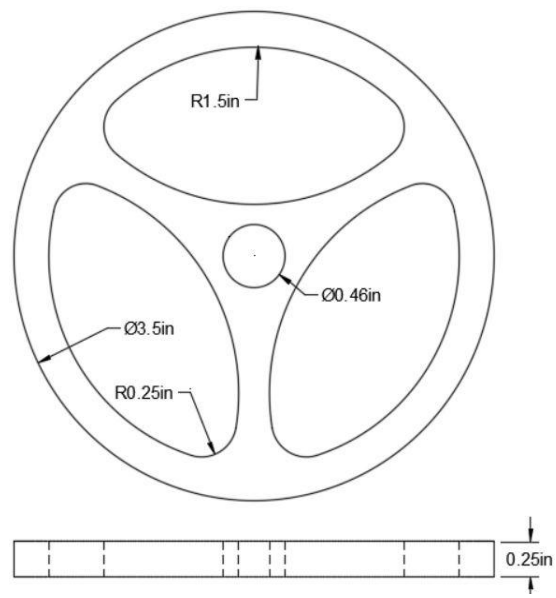
Toothbrush Holder

Design Challenge

Bottom Part



Top Part



***Chamfer All Edges: 0.01"**
***Tap & Die Threads: 1/2" - 20 NF**

Rough Stock

3.5"Diameter Aluminum Rod
- 0.875" Length (Bottom Part)
- 0.35" Length (Top Part)

0.5" Diameter Aluminum Rod
- 4" Length (Connecting Shaft)

Tool-Paths Required	
Both Top & Bottom Parts (Setup 1)	**Both Top & Bottom Parts (Setup 2)**
• 2D Face • Spot Drill & Drill • Adaptive or Pocket Clearing • 2D Contour • 2D Chamfer	• 2D Face • 2D Chamfer

Quiz

Section 2.3

NAME ____ **SCORE**____________

Match AND Label the following CNC machining abbreviations.

1. __E__ **DRO** ___*Digital Readout*___ **A.** Offset that allows the operator to use tools of different lengths

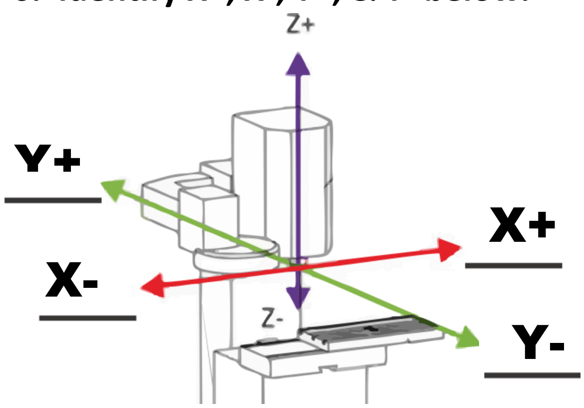
2. __C__ **ETS** ___*Electronic Tool Setter*___ **B.** X/Y/Z coordinates with respect to the part, instead of the mill position

3. __D__ **ATC** ___*Automatic Tool Changer*___ **C.** Device for automatically touching off tools to find their offset lengths

4. __B__ **WCS** ___*Work Coordinate System*___ **D.** Used to improve both the tool carrying capacity and production

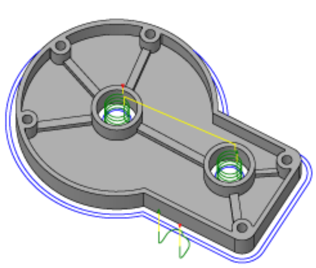
5. __A__ **TLO** ___*Tool Length Offset*___ **E.** Numeric display used to indicate the position of the cutting tool

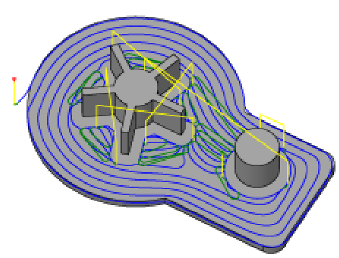
6. Identify X+, X-, Y+, & Y- below.

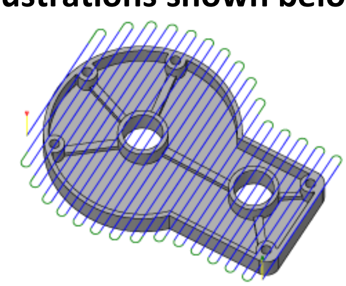


7. Draw arrows to illustrate the correct representation of a tool's offset.

Identify the following tool-path operations based on illustrations shown below.







8. ___*Contour*___ **9.** ___*Adaptive Clearing*___ **10.** ___*Face*___