

MODUL PRAKTIKUM

CNC MACHINING-1

Introduction to Programming & Simulation

CNC MILLING

DISUSUN OLEH:

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PROGRAM STUDI TEKNIK MESIN

FAKULTAS TEKNIK

UNIVERSITAS MUHAMMADIYAH SUMATERA BARAT



CNC Machines



Mazak VMC 410A-II
Three-Axis machining
center (Milling)



Fanuc 21i Series
CNC Machining center (Lathe)

CNC Simulator



MODUL -1

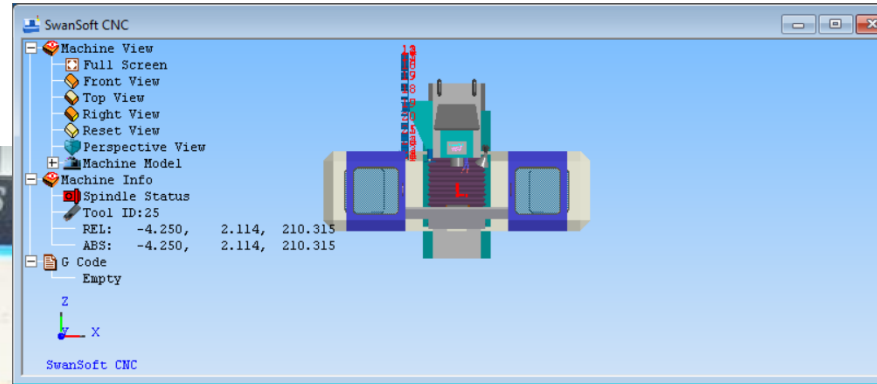
CNC MILLING



Vertical Machining Center

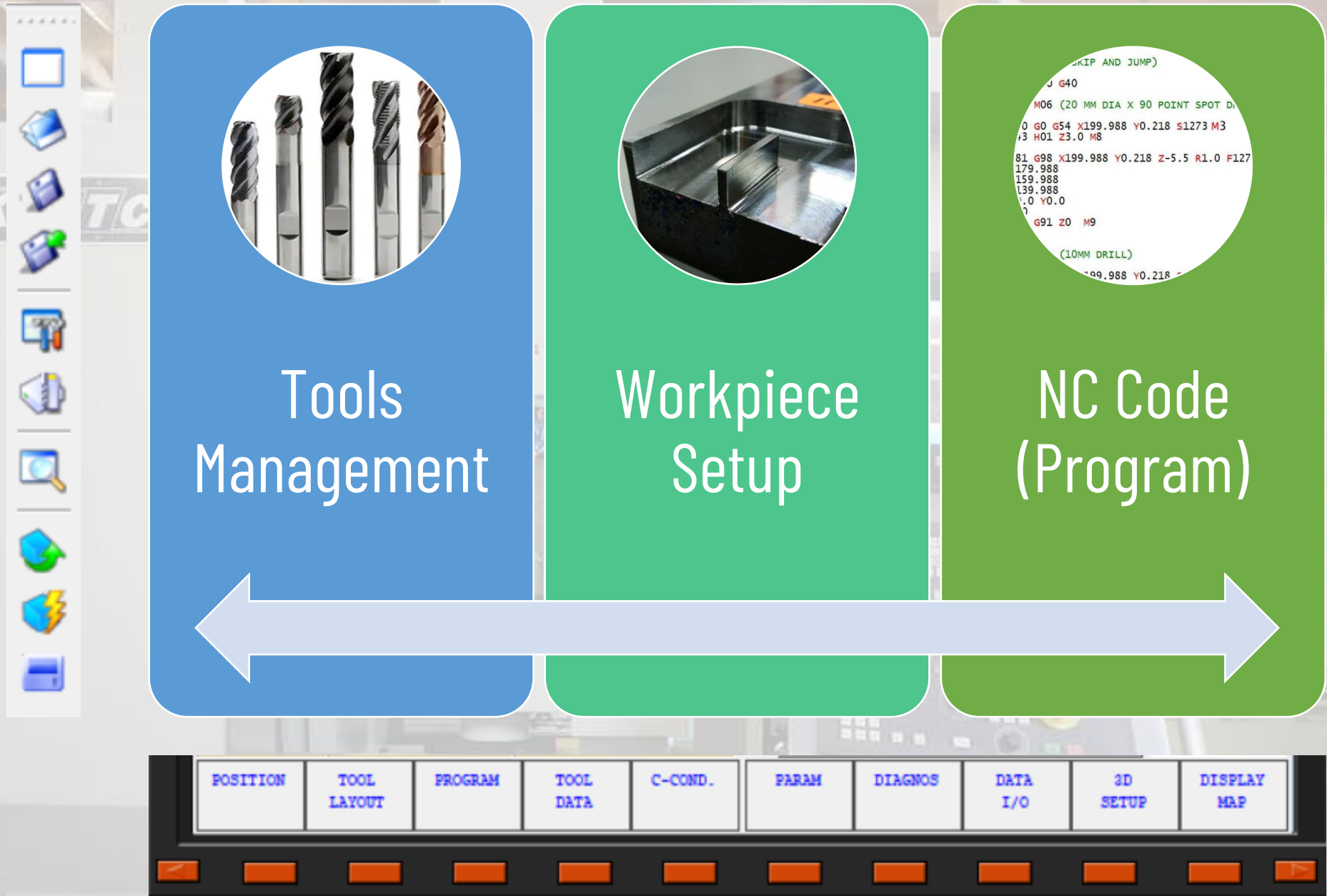


Mazak Nexus 410A-II



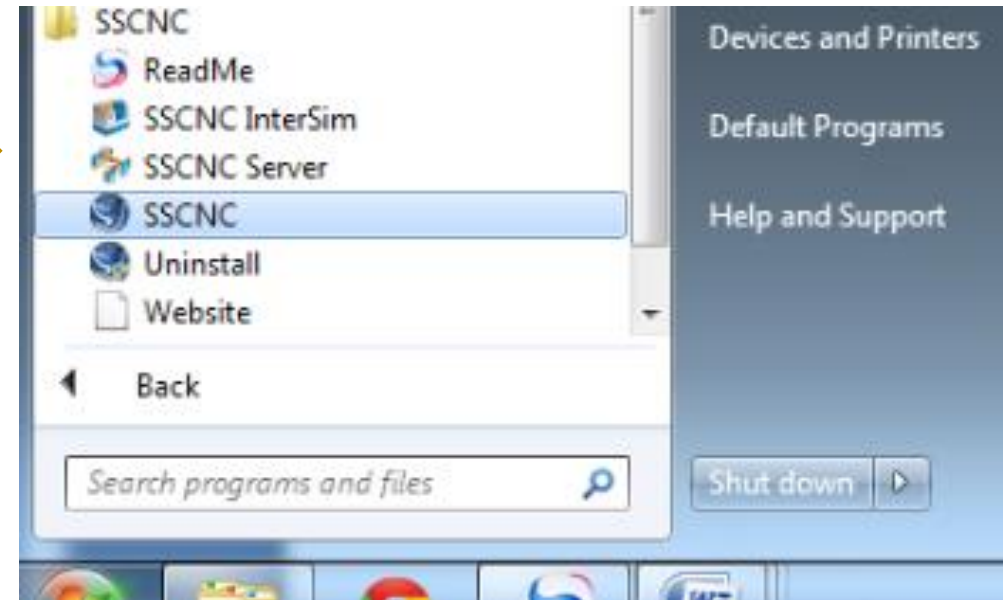
Mazak Nexus 410A-II
in SSCNC Simulator

Workflow



Starting the application

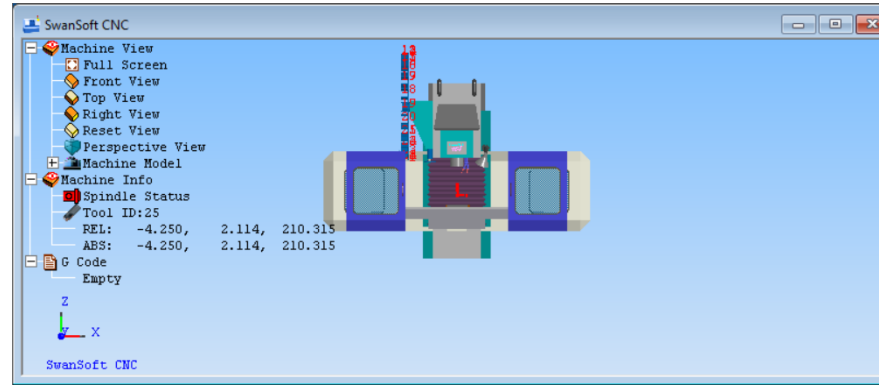
Pada Start menu Windows klik ikon SSCNC.
Jika tidak ada maka pada start menu:
klik all program → folder SSNC → ikon SSCNC



Pada kolom "CNC System" seperti disamping,
Pilih jenis mesin: **Mazak Nexus 410A-II**

Starting the application

Tampilan awal Mazak Nexus 410A-II pada SSCNC Simulator



Untuk mempermudah maka tampilan dapat di posisikan seperti dibawah ini:



Starting the machine

The image displays the Mazak Matrix Nexus CNC control interface. The top-left section features a large screen with the 'MAZATROL MATRIX NEXUS' logo. A red box highlights a green 'I' (Ready) button on the right side of the screen, with a red arrow pointing to it. Below the screen is a 'Mazak VOICE ADVISER' section. The bottom-left area contains a keyboard with various function keys like 'RESET', 'READY', 'ALARM', and 'CAPSLOCK'. The bottom-right area is a control panel with several dials (R0, R1, R2, 10, 25, 50, 100), buttons for axis movement (+X, -X, +Y, -Y, +Z, -Z, +4, -4), and a large yellow emergency stop button. The top-right window, titled 'SwanSoft CNC', shows a 3D model of the machine and a tree view with the following items:

- Machine View
 - Full Screen
 - Front View
 - Top View
 - Right View
 - Reset View
 - Perspective View
- Machine Model
- Machine Info
 - Spindle Status
 - Tool ID: 25
 - REL: -3.787, -0.051, 207.227
 - ABS: -3.787, -0.051, 207.227
- G Code
 - Empty

A 3D model of the machine is shown in the center of the window, and a coordinate system with X and Z axes is visible at the bottom left of the window.

Starting the machine

1. Switch off (release) Emergency Stop button
2. Turn off machine lock (Position > Machine Lock)

The image displays the Mazak NEXUS control panel and the SwanSoft CNC software interface. The control panel features a keyboard, a numeric keypad, and various function buttons. The software interface shows a 3D model of the machine and a list of machine parameters.

Mazak NEXUS Control Panel:

- Emergency stop:** A red button with a white symbol, highlighted with a red box.
- MACHINE LOCK:** A button with a red and yellow circular symbol, highlighted with a red box.
- Buttons:** STOP, MFL, SINGLE, MF2, RAPID, HOME, TAPE, MEMORY, X100, X10, X10, X10, MFL.

SwanSoft CNC Software Interface:

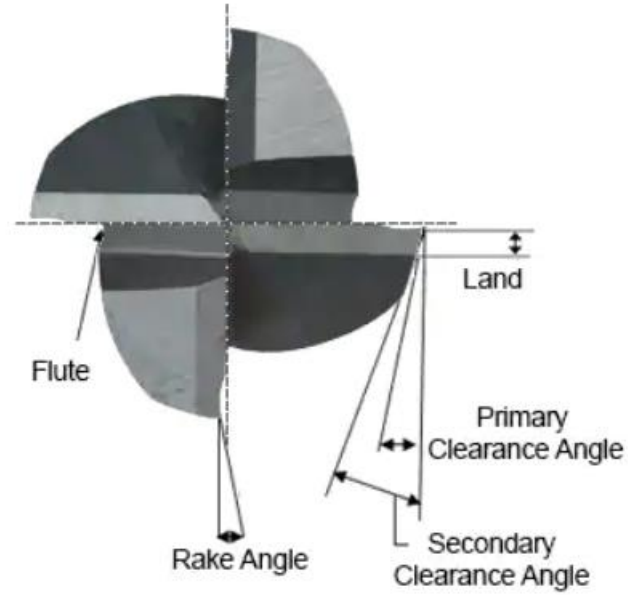
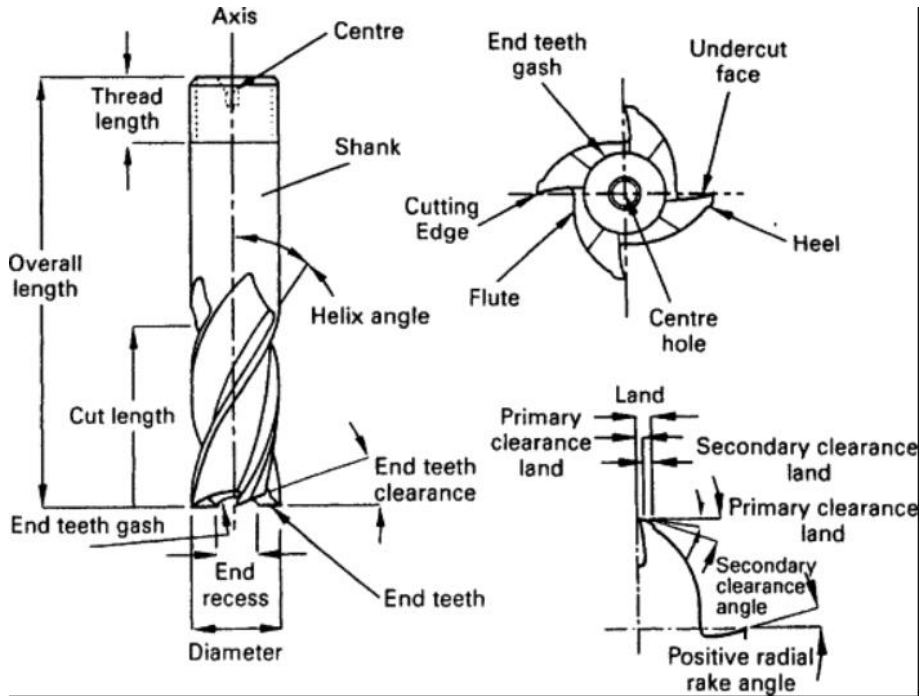
- Machine View:** A 3D model of the machine.
- Machine Info:** Spindle Status, Tool ID: 25, REL: -3.787, -0.051, 207.227, ABS: -3.787, -0.051, 207.227.
- G Code:** Empty.

Mazak NEXUS Software Interface:

- POSITION:** X -3.787, Y -0.051, Z 207.227.
- MACHINE:** X -403.787, Y -200.051, Z -54.773.
- Emergency stop:** A red button with a white symbol, highlighted with a red box.
- MACHINE LOCK:** A button with a red and yellow circular symbol, highlighted with a red box.

1: Tools Management

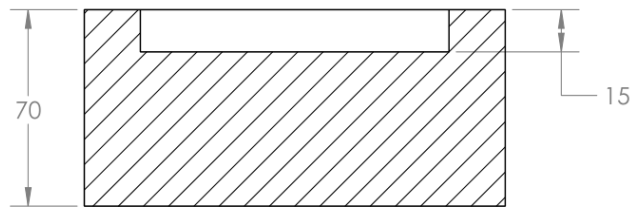
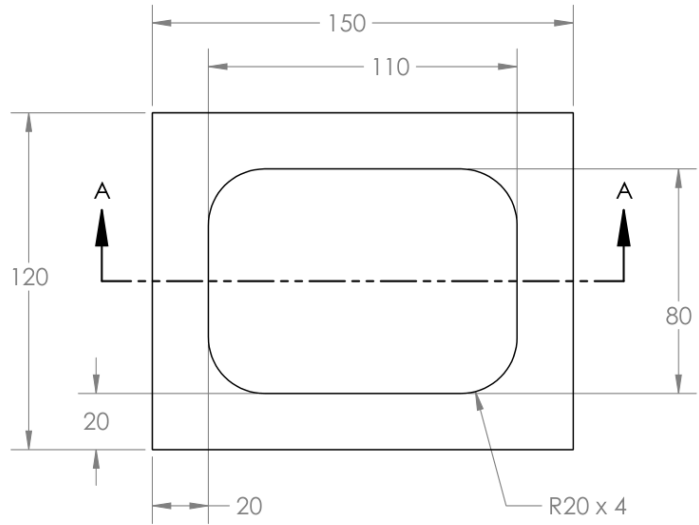
Solid endmills



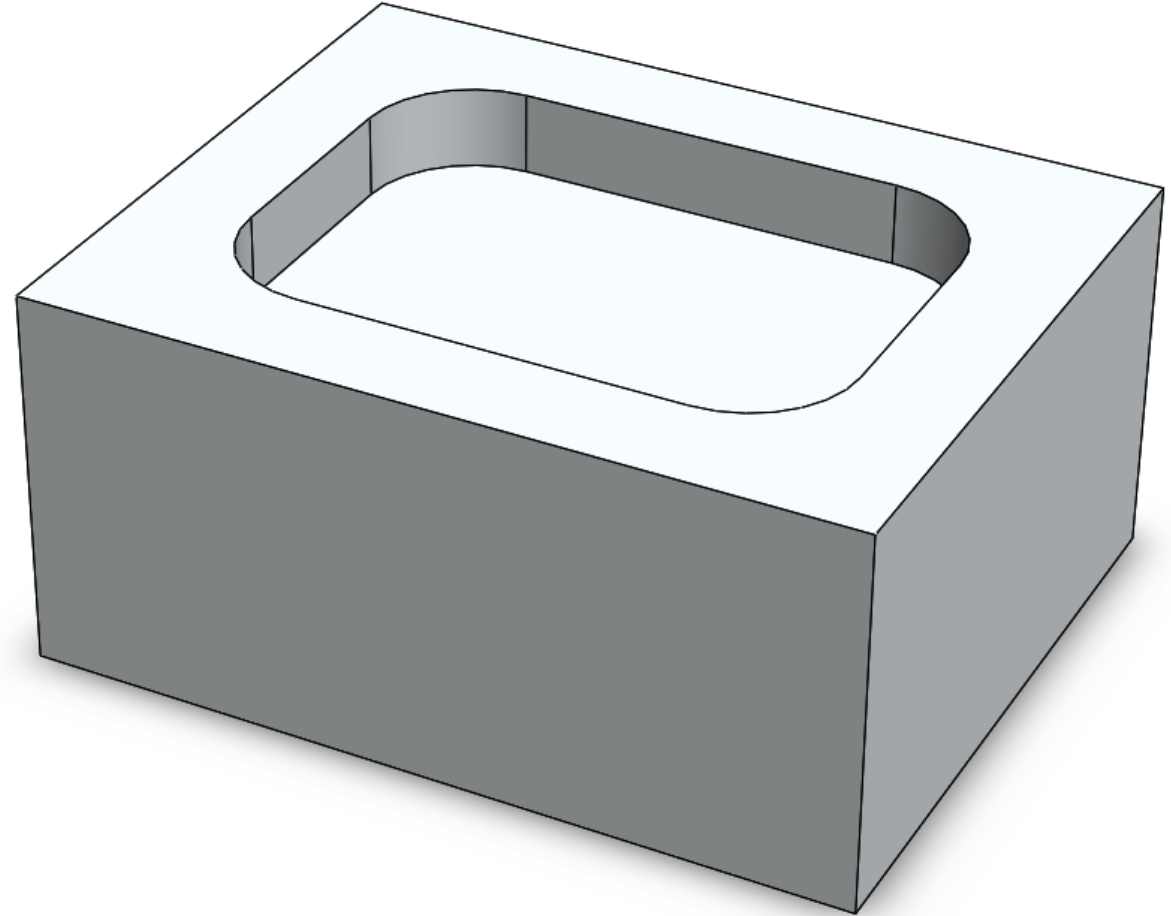
Insert endmill (Indexable endmill)



2: Workpiece Setup

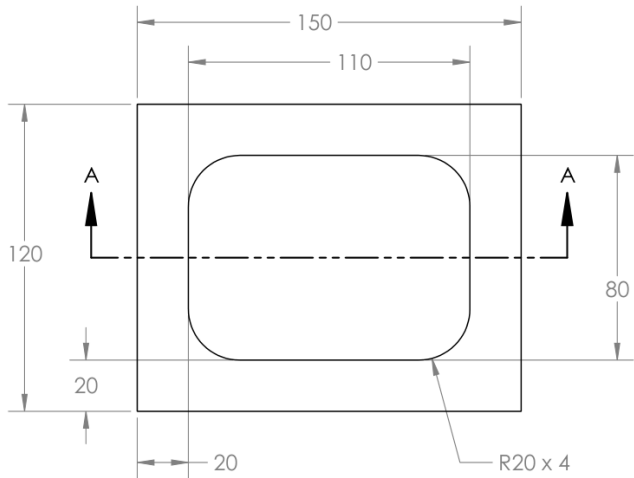


SECTION A-A



Milling Workpiece-1

2: Workpiece Setup

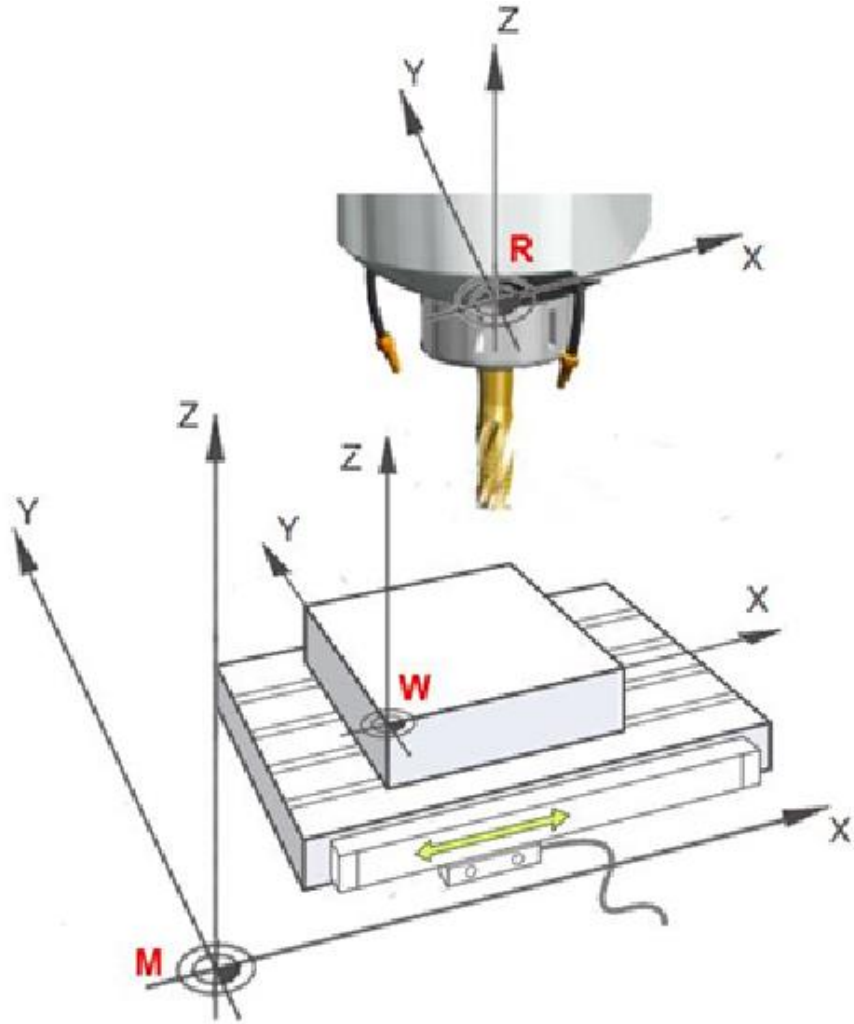


SECTION A-A

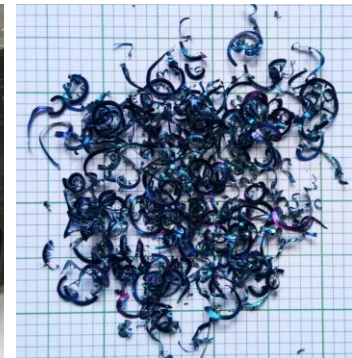
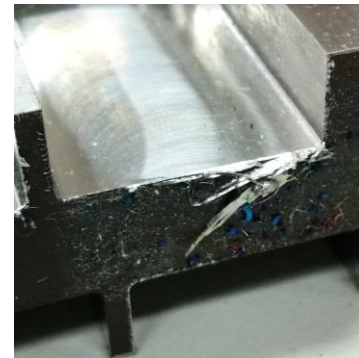
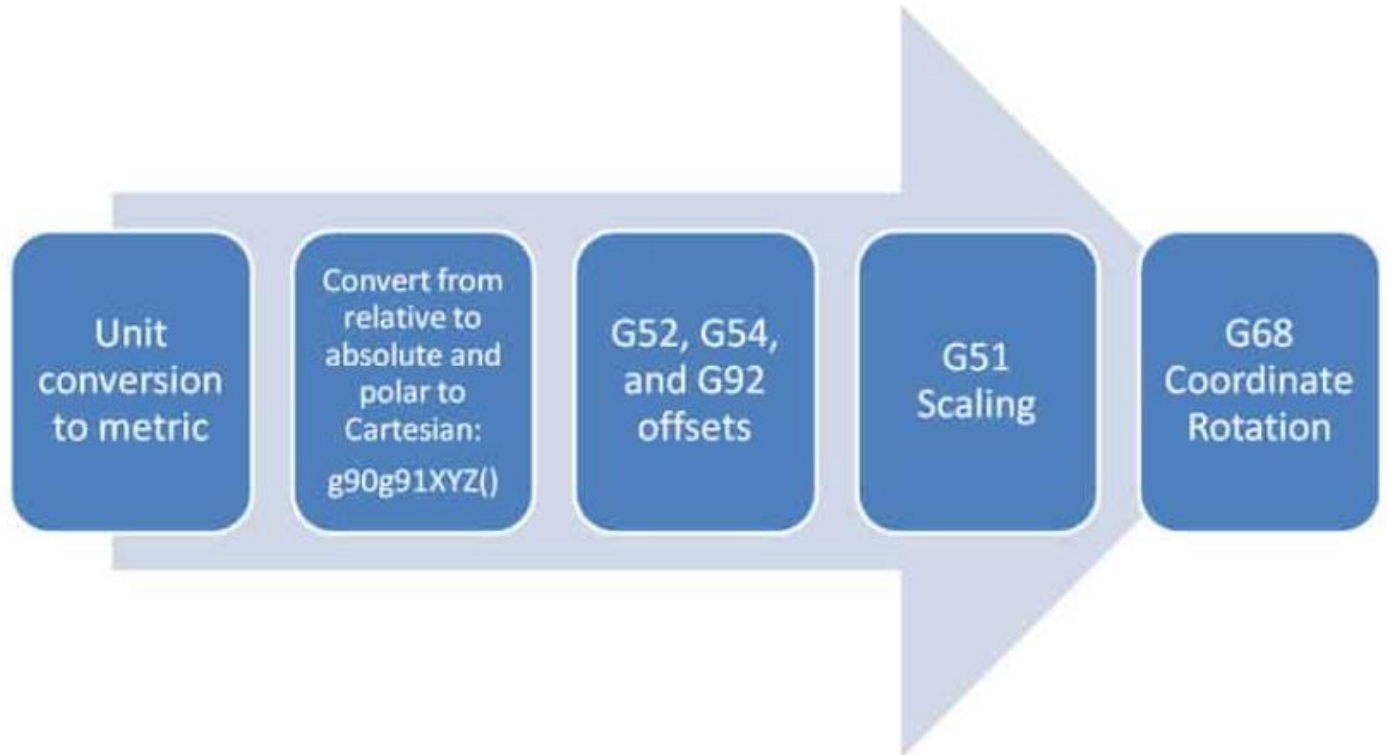
```
%  
N100 O0001  
N101 G21(G21 Program coordinates are mm)  
N102 (10MM CRB 4FL 22 LOC)  
N103 G91 G28 X0 Y0 Z0  
N104 (G91 Incremental programming of XYZ)  
N105 (G28 Return to Home Position)  
N106 T11 M06(M06 Tool Change)  
N107 S7868 M03 (M03 Spindle CW Rotation ON)
```

```
N200 (Pocket_Shape)  
N201 G90 G54 G98  
N202 G0 Z75.000000  
N203 G0 X45.610724 Y30.598979  
N204 G0 Z73.000000  
N205 G1 F5400 X45.610724 Y30.598979 Z65.000000  
N206 G2 F5400 I-10.617113 J-10.605368 K0.000000 X50.000000 Y19.921451 Z65.000000  
N207 G1 F5400 X50.000000 Y-19.921453 Z65.000000  
N208 G2 F5400 I-15.006389 J-0.072158 K0.000000 X34.921453 Y-35.000000 Z65.000000  
N209 G1 F5400 X-34.921453 Y-35.000000 Z65.000000  
N210 G2 F5400 I-0.072158 J15.006389 K0.000000 X-50.000000 Y-19.921451 Z65.000000  
N211 G1 F5400 X-50.000000 Y19.921453 Z65.000000  
N212 G2 F5400 I15.006389 J0.072158 K0.000000 X-34.921453 Y35.000000 Z65.000000  
N213 G1 F5400 X34.921453 Y35.000000 Z65.000000  
N214 G2 F5400 I0.072158 J-15.006389 K0.000000 X45.610724 Y30.598979 Z65.000000  
N215 G0 Z75.000000  
N216 G0 X45.266516Y-30.932731Z75.000000  
N217 G0 X45.266516Y-30.932731Z73.000000
```

2: Workpiece Setup > Work Offsets for CNC Fixtures (G54)

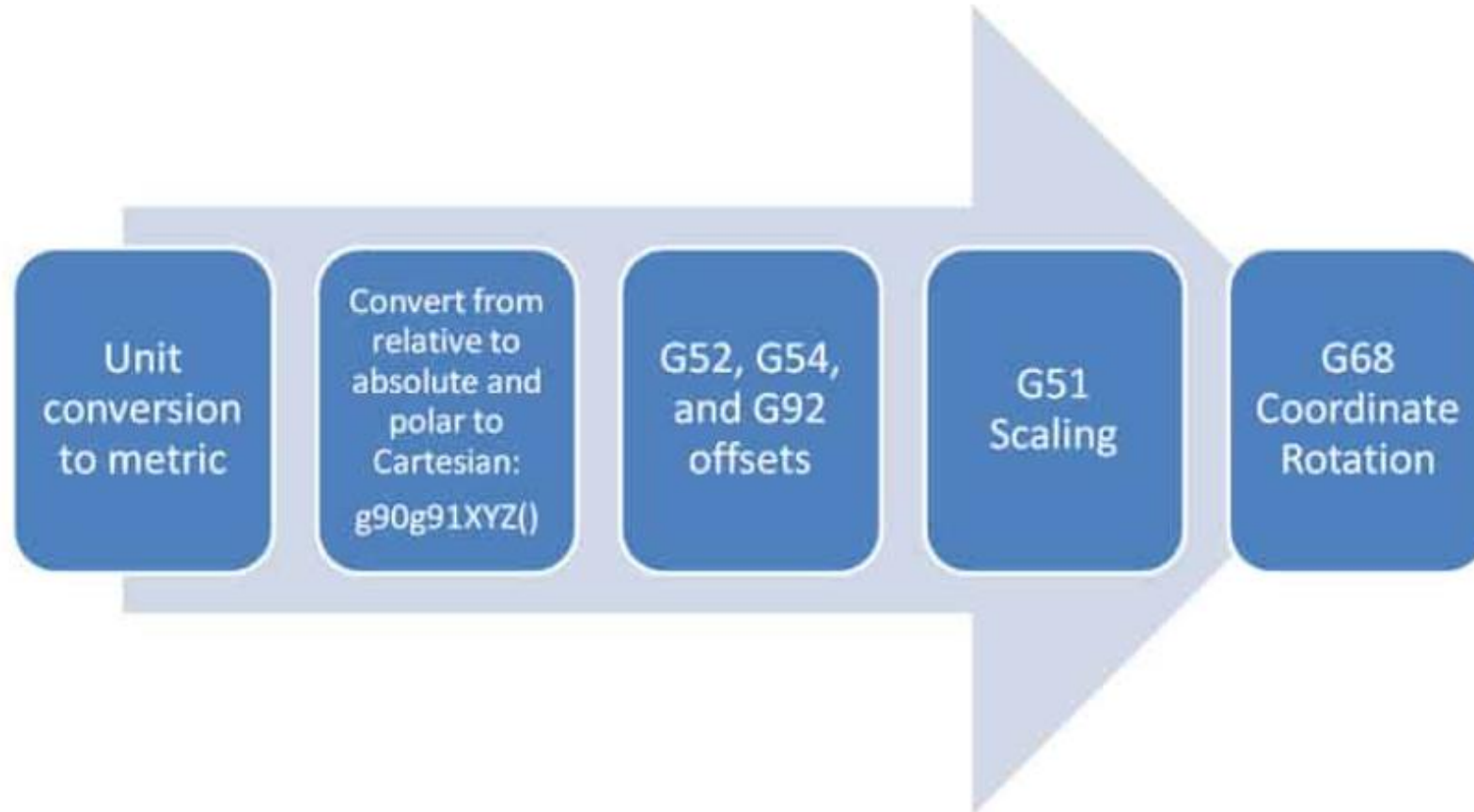


Part Zero/Program Zero



3: Program > Coordinate Transformation Pipeline

The following steps explain the conversion of coordinates in g-code to the active coordinate system the CNC machine uses for motion



3: Program > G90/G91: CNC Absolute & Incremental Programming

G90 and G91 tell the machine whether to use **absolute** or **incremental** coordinates.

That means:

- Absolute coordinates are measured from program zero (part zero), i.e., the program's origin.
- Relative moves are measured from the current position.

Application (Switching between G90 and G91):

```
G90 (Switch to absolute coordinates)
G0 X0Y0Z0 (Move to program origin at 0,0,0)
G91 (Switch to relative coordinates)
G0 X1Y1 (Move one unit right in X and unit right in Y)
G90 (Switch back to absolute coordinates)
```

3: Program > G02/G03: Circular Arc Moves

Circular interpolation is motion along a circular arc

- Circular interpolation is more demanding on the machine as **two axes have to be precisely coordinated**.
- Drawing a complete circle involves not just coordinated motion but reversal of direction at each of the 4 quadrant points. These would be the points corresponding to 0, 90, 180, and 270 degrees.
- If the machine has any backlash at all, it will be obvious at these reversals because there will be a glitch in the cut.



G02

Clockwise Arcs



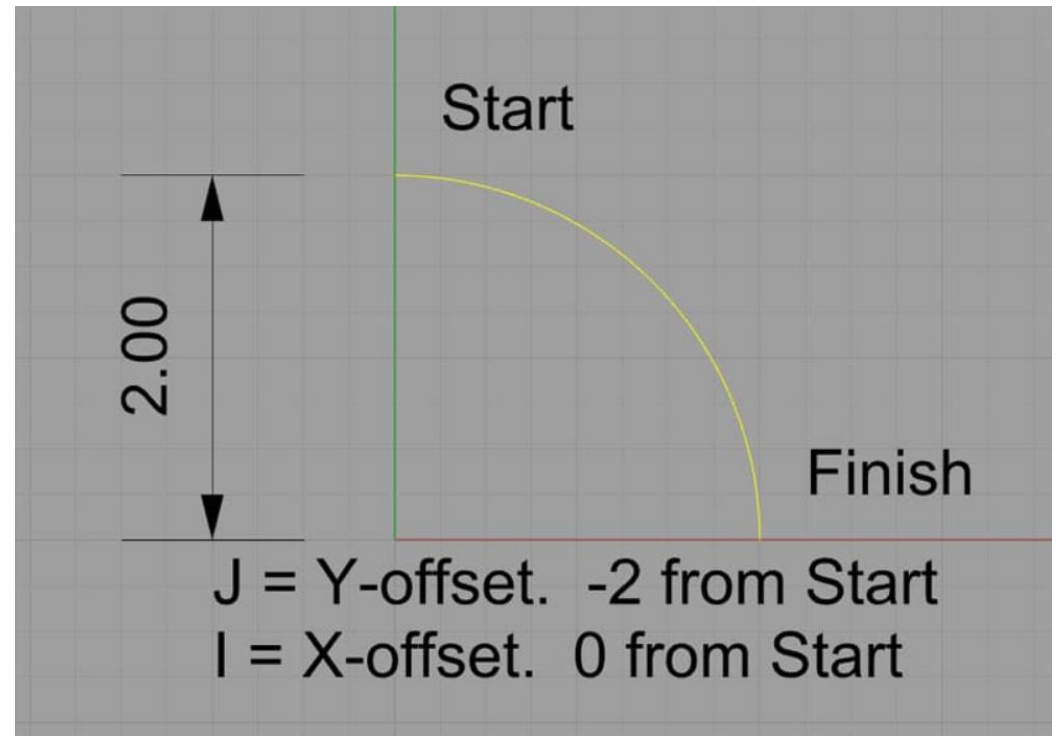
G03

Counter-Clockwise Arcs

3: Program > G02/G03: Circular Arc Moves

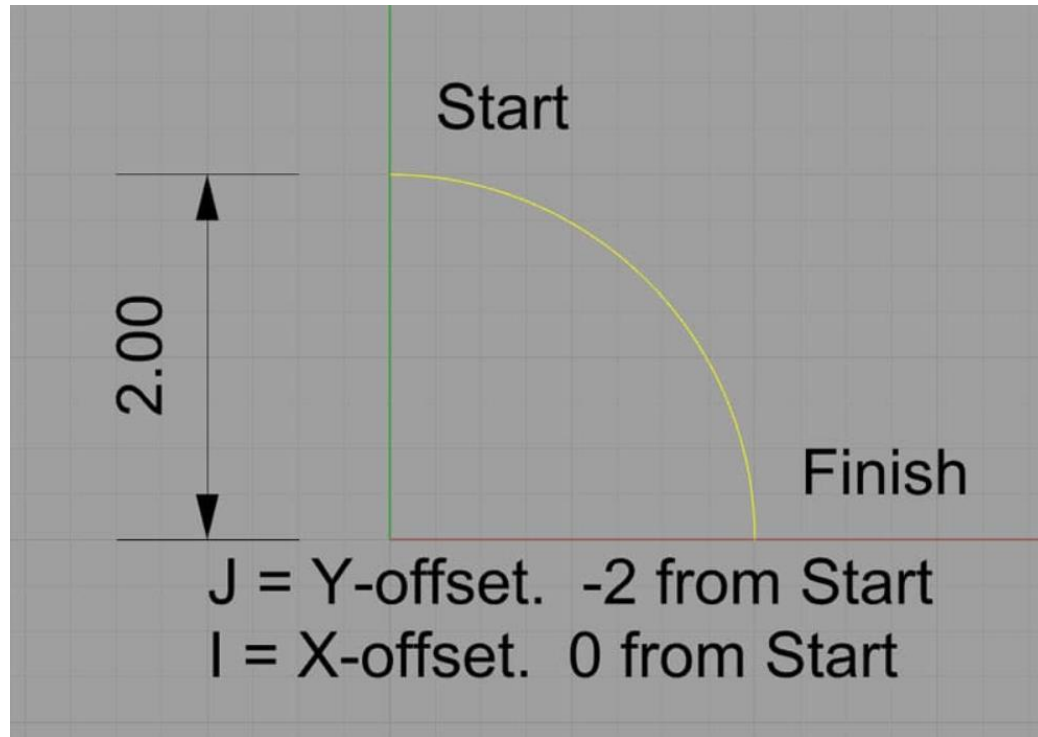
Defining an Arc for the Controller

- Arcs are defined in g-Code by identifying their 2 endpoints and the center which must be equidistant from each endpoint or an alarm will occur.
- The current control point, or location when the block is begun establishes one endpoint, and the other may be established by XYZ coordinates.
- The center is most commonly identified by using I, J, or K to establish relative offsets from the starting point of the arc to the center.



Typical clockwise arc

3: Program > G02/G03: Circular Arc Moves



- The arc starts at $X0Y2$ and finishes at $X2Y0$.
- The center is at $X0Y0$.
- Therefore:

```
G02 (Set up the clockwise arc mode)  
X2Y0 I0J-2.0
```

- The I and the J specify relative coordinates from the start point to the center.
- That is, if we add the I value to the starting point's X, and the J value to the starting point's Y, we get the X and Y for the center.

3: Program > Rapid Feed Rate, Feed Rate & Spindle Speed

- **Rapid feed rate** typically refers to the maximum feed rate achievable by the CNC machine.
- A high **feed rate** generally refers to a controlled higher feed rate that activates G01 (G01 is a high feed move, while G0 is a rapid feed move).

$$\text{Cutting Speed } V_c = \frac{\pi \times D \times n}{1,000}$$

$$\text{Spindle Speed } n = V_c \div \pi \div D \times 1,000$$

$$\text{Feed } V_f = n \times f_z \times Z$$

$$\text{Feed per Tooth } f_z = \frac{V_f}{n \times Z}$$

V_c = Cutting Speed (m/min)

π = 3.14 [The Circular Constant]

D = Diameter (mm)

n = Spindle Speed (min^{-1})

V_f = Feed (mm/min)

f_z = Feed per Tooth (mm/tooth)

Z = Number of Flutes

No of cutting edges (Z)	Chip Thickness (mm)	Feed rate (mm/min) at RPM		
		18000	21000	24000
1	0.1	1800	2100	2400
2	0.1	3600	4200	4800
3	0.1	5400	6300	7200
1	0.4	7200	8400	9600
2	0.4	14400	16800	19200
3	0.4	21600	25200	28800

3: Program > Program Format & Structure

Code	Function	Description
%	Tape Start/End	<ul style="list-style-type: none">▪ To denote the beginning and end of program.▪ Put one as the first line (block) and one as the last line (block).▪ Not all controllers require this.
O	Program Numbers (Letter "O")	<ul style="list-style-type: none">▪ The reference number needed by programs and subprograms▪ The O word (in g-code the letters are treated as "words" because each is a "word" telling the controller something to do)▪ May or may not be needed (depending on controllers)▪ Example: O1000
/	Block Skip/Block Delete	<ul style="list-style-type: none">▪ To make blocks drop out of the program temporarily without deleting them.▪ The operator can make quick changes or have optional sections of code that can be turned off and on from the control panel.▪ Example: /G00 X0 Y0 Z0
N	Sequence/Line Numbers	<ul style="list-style-type: none">▪ A unique way of identifying a particular block▪ Not all the blocks must have a sequence number, but it is common to do so.▪ Example: N100 G00 X0 Y0 Z0
	Spaces (in the program)	<ul style="list-style-type: none">▪ G-code ignores spaces in many cases▪ They're there simply to make the code more readable by operators▪ Example: G00 can be written as G 00
()	Comments	<ul style="list-style-type: none">▪ Anything placed in parenthesis is a comment that is ignored when executing the g-code program▪ Example: N100 G00 X0 Y0 Z0 (Rapid to Part Zero)

NOTE:

Blocks **mostly execute top to bottom** unless they are ordered to do something different explicitly via macros and subprograms, BUT **blocks do not necessarily execute left to right**

3: Program > Frequently Used G-Codes & M-Codes

CODE	CATEGORY	DESCRIPTION
G0 (G00)	Motion	Move in a straight line at rapid speed
G1 (G01)	Motion	Move in a straight line at last speed commanded by a feedrate
G2 (G02)	Motion	Clockwise circular arc at feedrate
G3 (G03)	Motion	Counter-clockwise circular arc at feedrate
G21	Coordinate	Program coordinates are mm
G28	Motion	Return to home position
G54	Coordinate	Work coordinate system (1 st Workpiece)
G90	Coordinate	Absolute programming of XYZ
G91	Coordinate	Incremental programming of XYZ
G98	Canned	Return to initial Z plane after canned cycle

3: Program > Frequently Used G-Codes & M-Codes

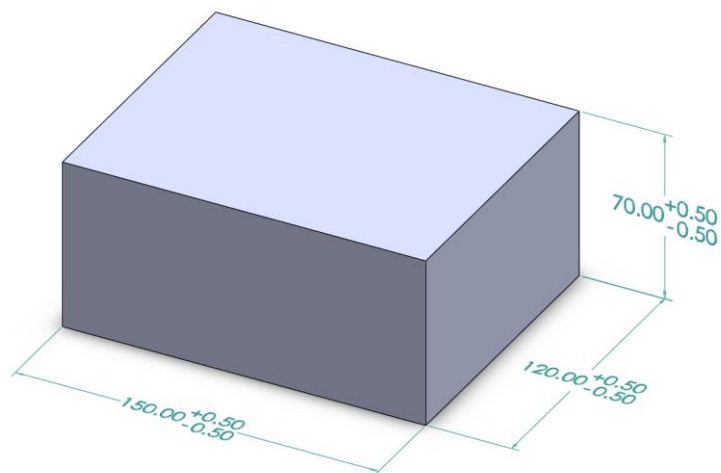
CODE	CATEGORY	DESCRIPTION
M03	M-Codes	Spindle ON (Clockwise rotation)
M04	M-Codes	Spindle ON (Counter-clockwise rotation)
M05	M-Codes	Spindle Stop
M06	M-Codes	Tool Change
M07	M-Codes	Mist coolant ON
M08	M-Codes	Flood coolant ON
M09	M-Codes	Coolant OFF
M30	M-Codes	End of program, Rewind and Reset Modes

PEMROGRAMAN CNC

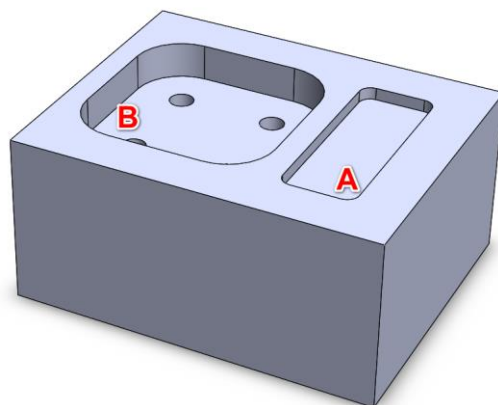
TUGAS PRAKTIKUM MILLING (FRAIS)

Semester Ganjil 2022/2023

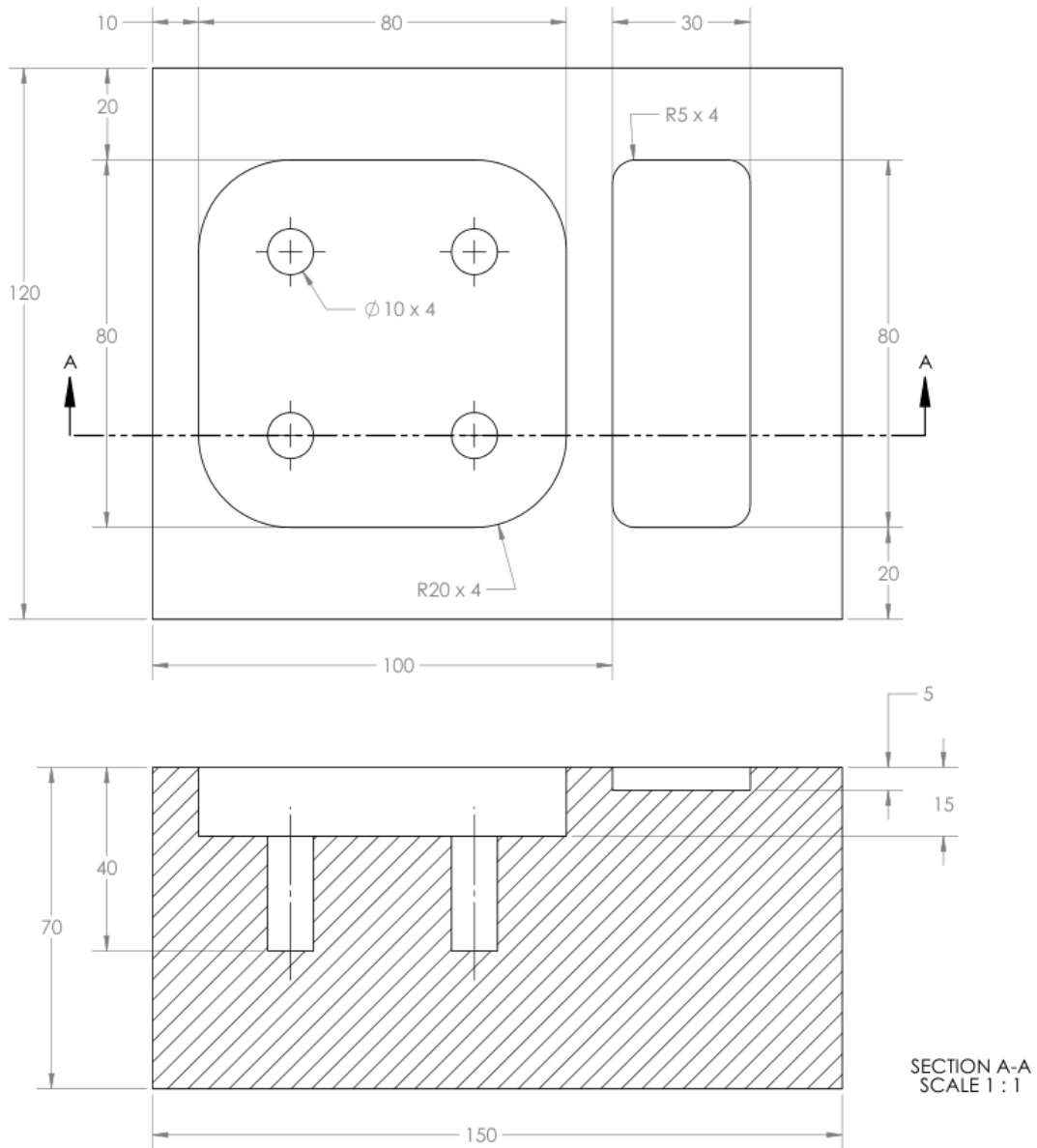
Perusahaan A mempercayakan Anda untuk membuat sebuah produk (final part) dengan menggunakan stock Aluminium Alloy (6061-T6) berdimensi 150 mm × 120 mm × 70 mm (Gambar 1). Benda kerja yang akan diproses memiliki dua buah fitur pocket, Pocket A dan Pocket B (Gambar 2), dan empat buah *blind hole* yang terletak pada dasar Pocket B. Detail gambar kerja pada Gambar 3 menunjukkan seluruh dimensi yang diperlukan untuk proses produksi.



Gambar 1. Dimensi stock Aluminium Alloy (6061-T6)



Gambar 2. Fitur Pocket A dan Pocket B pada benda kerja



Gambar 3. Gambar kerja (satuan dalam mm)

Dengan menggunakan sebuah alat potong (cutting tool) berbahan carbide berdiameter potong 10 mm berjenis *centered flat end cutter*, lakukanlah simulasi pemotongan menggunakan Mazak Vertical Machining Center 410. Persiapkan program sesuai dengan instruksi yang tertera pada Tugas-1 dan Tugas-2 berikut ini.

>> TUGAS-1 (Pocket A)

1.1 Instruksi

Dengan menggunakan simulator SSCNC Mazak Vertical Machining Center 410, rumuskan g-code yang diperlukan untuk membuat Pocket A dan simulasikan proses pemotongan. Gunakan fitur *Save Report* simulator untuk menghasilkan laporan berbentuk html dan serahkan laporan tersebut melalui tab penugasan (*assignment*) “Tugas-1” pada penghujung kelas.

1.2 Catatan

- Sebelum laporan dicetak oleh simulator, pastikan produk dapat terlihat dengan jelas pada display CNC mesin karena simulator akan membuat tangkapan layar dari pekerjaan Anda.
- Tuliskan label “Tugas-1” diikuti NRP dan nama Anda sebagai nama file. Contoh: *Tugas-1 Rahman Mustafa 20203xxx.htm*. **<Perhatian!>** Kesalahan dalam penulisan nama dapat berakibat pada tidak dikenalnya dokumen dalam proses penilaian.
- Serahkan seluruh file yang dihasilkan oleh simulator melalui Google Classroom dan pastikan Anda menyimpan dan memiliki salinan dari proyek pekerjaan Anda.
- **<Mohon diingat!>** Keterlambatan dalam menyerahkan tugas melewati batas waktu yang ditentukan dapat berujung pada pengurangan nilai. Menyalin laporan dari rekan perkuliahan termasuk tindakan yang tidak dapat dibenarkan dan dapat berujung pada dianulirnya laporan yang Anda serahkan.

>> TUGAS-2 (Pocket B)

2.1 Instruksi

Lampiran A menunjukkan data koordinat yang diperlukan dalam proses pembuatan Pocket B dari benda kerja pada Gambar 2. Lengkapi dan modifikasi (jika diperlukan) data tersebut sehingga dapat digunakan sebagai g-code untuk memproduksi Pocket B. Gunakan g-code yang telah anda rangkai untuk proses simulasi (Mazak 410) dan serahkan laporan (Report) melalui panel Tugas-2 pada Google Classroom sebelum tenggat waktu yang telah ditentukan.

2.2 Catatan

- Sebelum laporan dicetak oleh simulator, pastikan produk dapat terlihat dengan jelas pada display CNC mesin karena simulator akan membuat tangkapan layar dari pekerjaan Anda.
- Tuliskan label “Tugas-2” diikuti NRP dan nama Anda sebagai nama file. Contoh: *Tugas-2 Rahman Mustafa 20203xxx.htm*. **<Perhatian!>** Kesalahan dalam penulisan nama dapat berakibat pada tidak dikenalnya dokumen dalam proses penilaian.
- Serahkan seluruh file yang dihasilkan oleh simulator melalui Google Classroom dan pastikan Anda menyimpan dan memiliki salinan dari proyek pekerjaan Anda.
- **<Mohon diingat!>** Keterlambatan dalam menyerahkan tugas melewati batas waktu yang ditentukan dapat berujung pada pengurangan nilai. Menyalin laporan dari rekan perkuliahan termasuk tindakan yang tidak dapat dibenarkan dan dapat berujung pada dianulirnya laporan yang Anda serahkan.

LAMPIRAN A

(Pocket B)

Z75.000000
X5.604865 Y30.604841
Z73.000000
X5.604865 Y30.604841 Z65.000000
I-10.611255 J-10.611230 K0.000000 X10.000000 Y19.921453 Z65.000000
X10.000000 Y-19.921453 Z65.000000
I-15.006389 J-0.072158 K0.000000 X-5.078547 Y-35.000000 Z65.000000
X-44.921453 Y-35.000000 Z65.000000
I-0.072158 J15.006389 K0.000000 X-60.000000 Y-19.921453 Z65.000000
X-60.000000 Y19.921453 Z65.000000
I15.006389 J0.072158 K0.000000 X-44.921453 Y35.000000 Z65.000000
X-5.078547 Y35.000000 Z65.000000
I0.072158 J-15.006389 K0.000000 X5.604865 Y30.604841 Z65.000000
Z75.000000
X10.000000 Y-19.921453 Z75.000000
X10.000000 Y-19.921453 Z73.000000
X10.000000 Y-19.921453 Z65.000000
X10.000000 Y19.921453 Z65.000000
I-14.984580 J0.079007 K0.000000 X0.000000 Y34.131909 Z65.000000
X0.000000 Y-34.131909 Z65.000000
I-4.995838 J13.937467 K0.000000 X-5.078547 Y-35.000000 Z65.000000
X-10.000000 Y-35.000000 Z65.000000
X-10.000000 Y35.000000 Z65.000000
X-20.000000 Y35.000000 Z65.000000
X-20.000000 Y-35.000000 Z65.000000
X-30.000000 Y-35.000000 Z65.000000
X-30.000000 Y35.000000 Z65.000000
X-40.000000 Y35.000000 Z65.000000
X-40.000000 Y-35.000000 Z65.000000
X-44.921453 Y-35.000000 Z65.000000
I-0.082708 J14.805559 K0.000000 X-50.000000 Y-34.131909 Z65.000000
X-50.000000 Y34.131909 Z65.000000
I4.984580 J-14.131449 K0.000000 X-60.000000 Y19.921453 Z65.000000
X-60.000000 Y-19.921453 Z65.000000
X-60.000000 Y-19.921453 Z60.000000
X-60.000000 Y19.921453 Z60.000000
I14.984580 J0.079007 K0.000000 X-50.000000 Y34.131909 Z60.000000
X-50.000000 Y-34.131909 Z60.000000
I4.995838 J13.937468 K0.000000 X-44.921453 Y-35.000000 Z60.000000
X-40.000000 Y-35.000000 Z60.000000
X-40.000000 Y35.000000 Z60.000000
X-30.000000 Y35.000000 Z60.000000
X-30.000000 Y-35.000000 Z60.000000
X-20.000000 Y-35.000000 Z60.000000
X-20.000000 Y35.000000 Z60.000000
X-10.000000 Y35.000000 Z60.000000
X-10.000000 Y-35.000000 Z60.000000
X-5.078547 Y-35.000000 Z60.000000
I0.082708 J14.805558 K0.000000 X0.000000 Y-34.131909 Z60.000000
X0.000000 Y34.131909 Z60.000000
I-4.984580 J-14.131449 K0.000000 X10.000000 Y19.921453 Z60.000000
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I-15.006389 J-0.072158 K0.000000 X-5.078547 Y-35.000000 Z60.000000
X-44.921453 Y-35.000000 Z60.000000
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X-5.078547 Y35.000000 Z60.000000
I0.072158 J-15.006389 K0.000000 X10.000000 Y19.921453 Z60.000000
X10.000000 Y-19.921453 Z60.000000
X10.000000 Y-19.921453 Z55.000000
I-15.006389 J-0.072158 K0.000000 X-5.078547 Y-35.000000 Z55.000000

X-44.921453 Y-35.000000 Z55.000000
I-0.072158 J15.006389 K0.000000 X-60.000000 Y-19.921453 Z55.000000
X-60.000000 Y19.921453 Z55.000000
I15.006389 J0.072158 K0.000000 X-44.921453 Y35.000000 Z55.000000
X-5.078547 Y35.000000 Z55.000000
I0.072158 J-15.006389 K0.000000 X10.000000 Y19.921453 Z55.000000
X10.000000 Y-19.921453 Z55.000000
X10.000000 Y-19.921453 Z55.000000
X10.000000 Y19.921453 Z55.000000
I-14.984580 J0.079007 K0.000000 X0.000000 Y34.131909 Z55.000000
X0.000000 Y-34.131909 Z55.000000
I-4.995838 J13.937467 K0.000000 X-5.078547 Y-35.000000 Z55.000000
X-10.000000 Y-35.000000 Z55.000000
X-10.000000 Y35.000000 Z55.000000
X-20.000000 Y35.000000 Z55.000000
X-20.000000 Y-35.000000 Z55.000000
X-30.000000 Y-35.000000 Z55.000000
X-30.000000 Y35.000000 Z55.000000
X-40.000000 Y35.000000 Z55.000000
X-40.000000 Y-35.000000 Z55.000000
X-44.921453 Y-35.000000 Z55.000000
I-0.082708 J14.805559 K0.000000 X-50.000000 Y-34.131909 Z55.000000
X-50.000000 Y34.131909 Z55.000000
I4.984580 J-14.131449 K0.000000 X-60.000000 Y19.921453 Z55.000000
X-60.000000 Y-19.921453 Z55.000000
Z75.000000
Z75.000000

(Drilling)

(Begin Drilling)

Z75.000000
X-5.000000 Y-20.000000
Z73.000000
R73.000000 X-5.000000 Y-20.000000 Z30.000000
X-5.000000 Y20.000000
Z73.000000
R73.000000 X-5.000000 Y20.000000 Z30.000000
X-45.000000 Y20.000000
Z73.000000
R73.000000 X-45.000000 Y20.000000 Z30.000000
X-45.000000 Y-20.000000
Z73.000000
R73.000000 X-45.000000 Y-20.000000 Z30.000000
Z73.000000
Z75.000000