COMPUTER NUMERICAL CONTROL OF MACHINE TOOLS

Laboratory for Manufacturing Systems and Automation
Department of Mechanical Engineering and Aeronautics
University of Patras, Greece

Dr. Dimitris Mourtzis

Associate professor

Patras, 2016

Chapter 5:
Programming Coordinates

Table of Contents

Objectives of Chapter 5

- Explain what a **hole operation** is

- Define the **drill selection** procedure

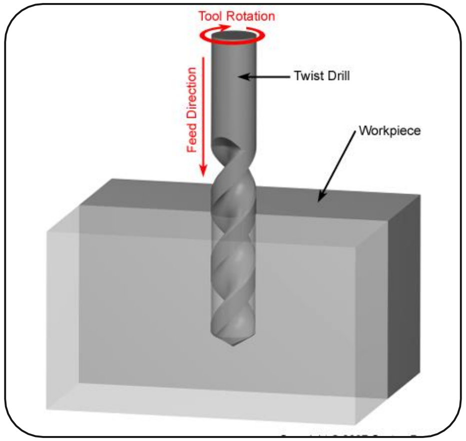
- **Program hole operation coordinates** using absolute and incremental positioning

- **Program milling coordinates** using absolute and incremental positioning

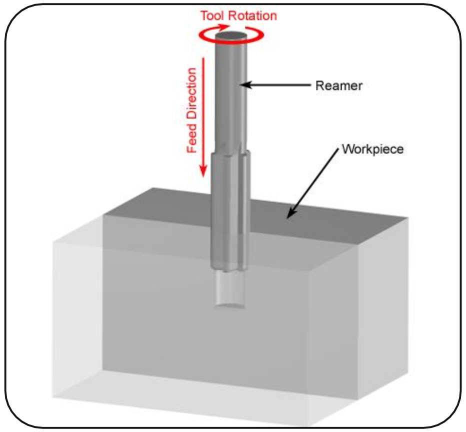
Hole Operations

- **Drilling** is one of the most common processes
- In most cases, the **creation of a hole** requires the **repetition of particular steps**
- **The standardization of these steps** allows the introduction of **drilling cycles** to simplify programming
- For drilling a hole a **control method from point to point** is used
  - Control the movement of the cutter at X-Y axes with maximum speed
  - Control of the Z axis with cutting speed (feed-rate)

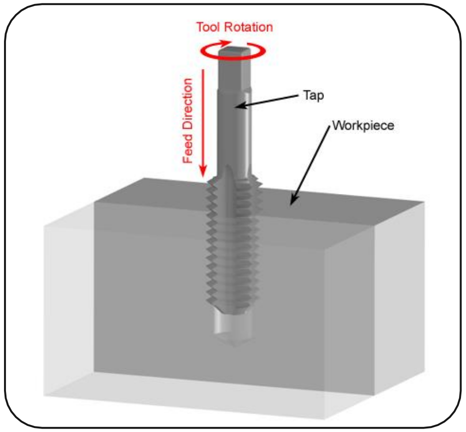
Hole operations



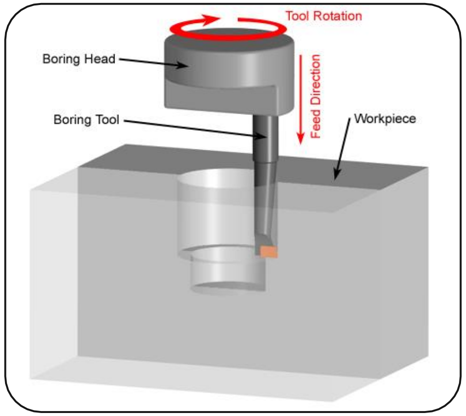
Drilling



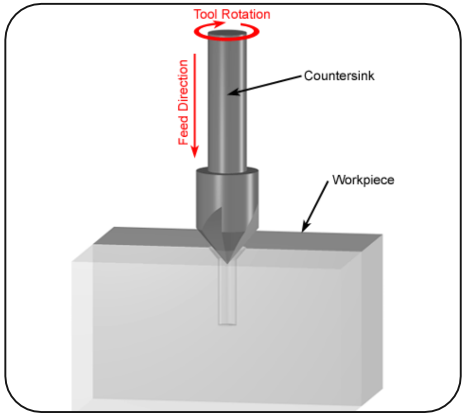
Reaming



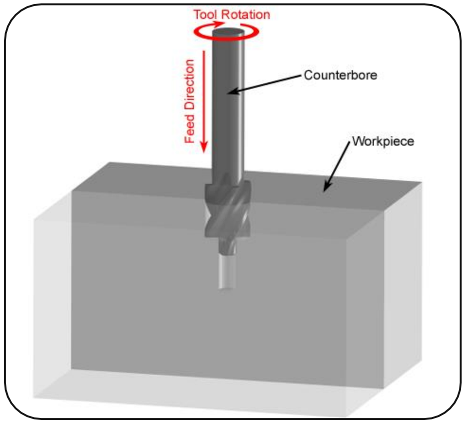
Tapping



Boring



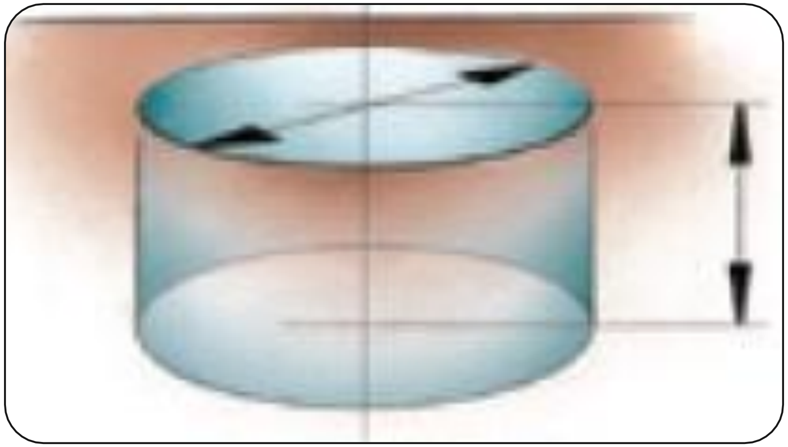
Counterinking



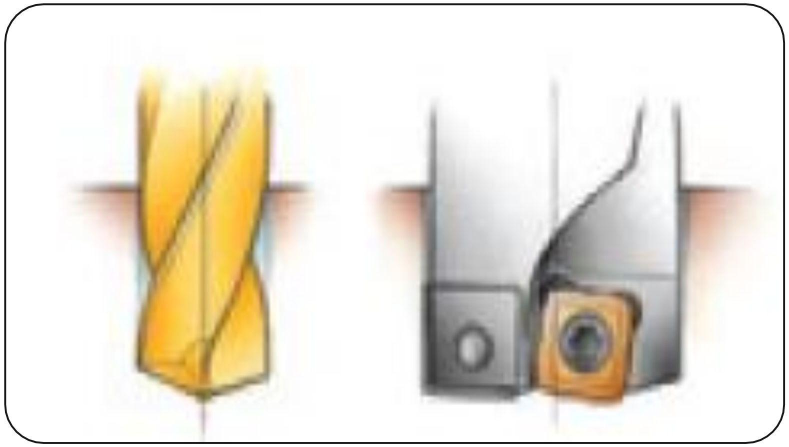
Counterboring

FIGURE 1:Hole Operations (courtesy of CustomPartNet)

Drill Selection Procedure



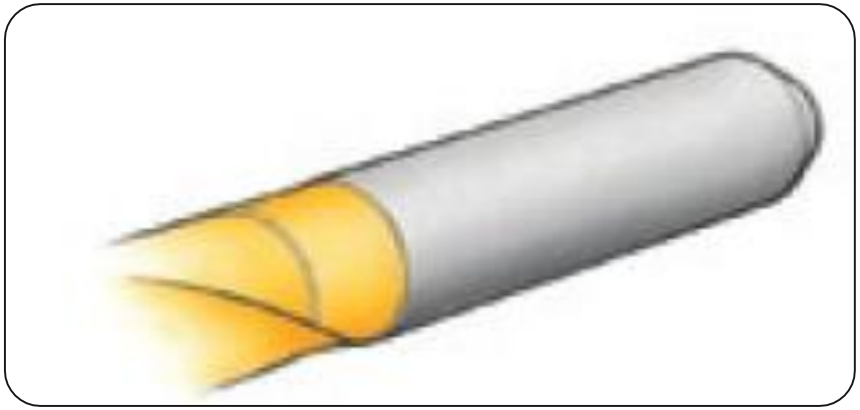
1. Define your **hole diameter**, **depth** and **quality** requirements. Consider also **production economy** and **machining reliability aspects**



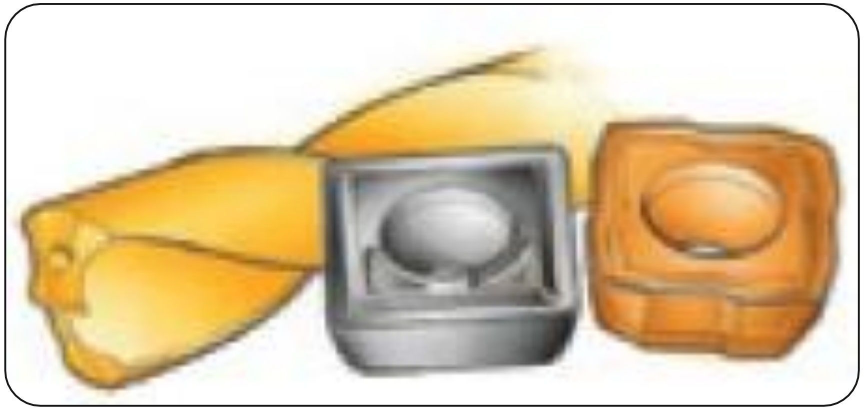
2. Select the **type of drill**: Choose a drill for roughing and/or finishing holes. Check that the drill is **suitable for the workpiece material**, **hole quality demands** and that it provides the best **hole economy**

Source :Sandvik Coromant

Drill Selection Procedure



3. Choose the **drill grade** and **geometry**. If an indexable insert drill has been selected, **inserts** have to be selected separately. Find the right inserts for the **drill diameter** and recommended **geometry** and **grades** for the workpiece material



4. Select the **right style**. Many drills are available with different **mounting** options. Find the style compatible with the machine

Source :Sandvik Coromant

Machining Holes

- Holes are either **made** or **finish machined**. Most workpieces have at least one hole and **depending upon the function of the hole**, it needs machining to various **limitations**

- The **main factors** that characterize a hole from a machining point of view are:
  - **Diameter**
  - **Depth**
  - **Quality**
  - **Material**
  - **Conditions**
  - **Reliability**
  - **Productivity**

Source :Sandvik Coromant

Drilling a Hole

Minimum number of steps for drilling a hole:

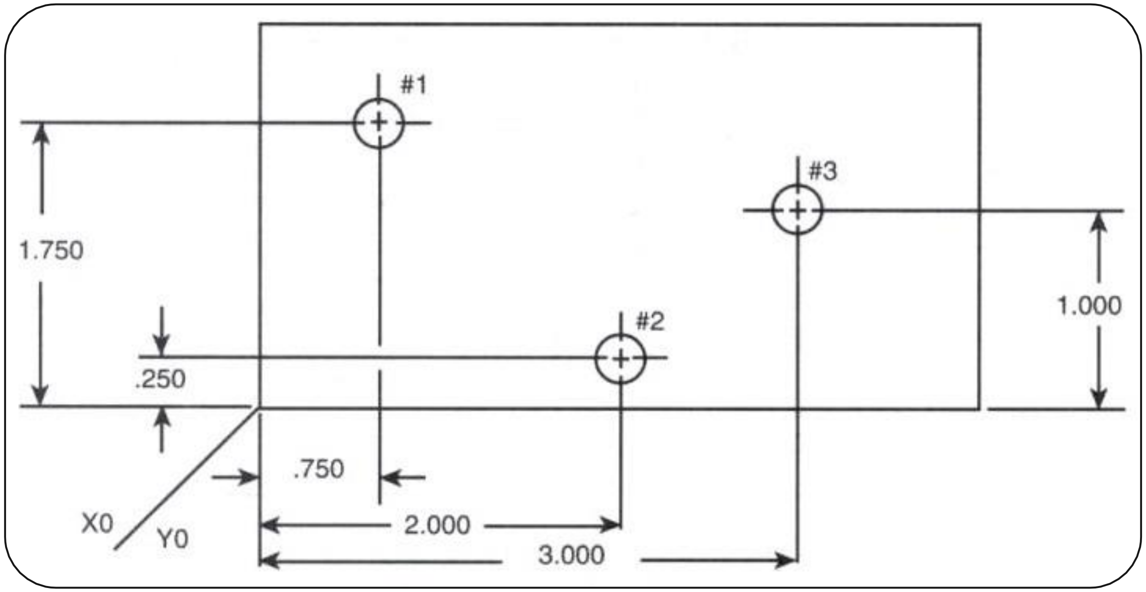
- **1st Step** : Rapid cutting tool movement at the hole ... *movement in axes X and / or Y*
- **2nd Step** : Rapid movement at the cutting height .... *movement in the Z axis*
- **3rd Step** : Cutting with feed-rate speed to the desired depth of the hole .... *movement in the Z axis*
- **4th Step** : Return to the reference plane .... *movement in the Z axis*

Different Types of Canned Drilling Cycles

G code

- **G80** - Cancel canned cycle
- **G81** - Simple drilling cycle
- **G82** - Drilling cycle with dwell
- **G83** - Peck drilling cycle
- **G84** - Tapping cycle, right-hand thread
- **G85** - Reaming cycle
- **G86** - Boring cycle and spindle stop

Hole Operations



Hole Operations:
- Drilling
- Reaming
- Boring
- Taping

FIGURE 2: Datum dimensioned part drawing

Absolute Positioning – Datum Dimensioning - Drilling

- The holes on the part are to be drilled
- All positions on the part are taken from the (X0, Y0) point at the lower left corner of the part
- The hole #1 will have coordinates of (X0.7500, Y1.7500)
- The hole #2 will have coordinates of (X2.0000, Y0.2500)
- The hole #3 will have coordinates of (X3.0000, Y1.0000)
- If no sign given the machine will assume a positive movement

Hole Operations

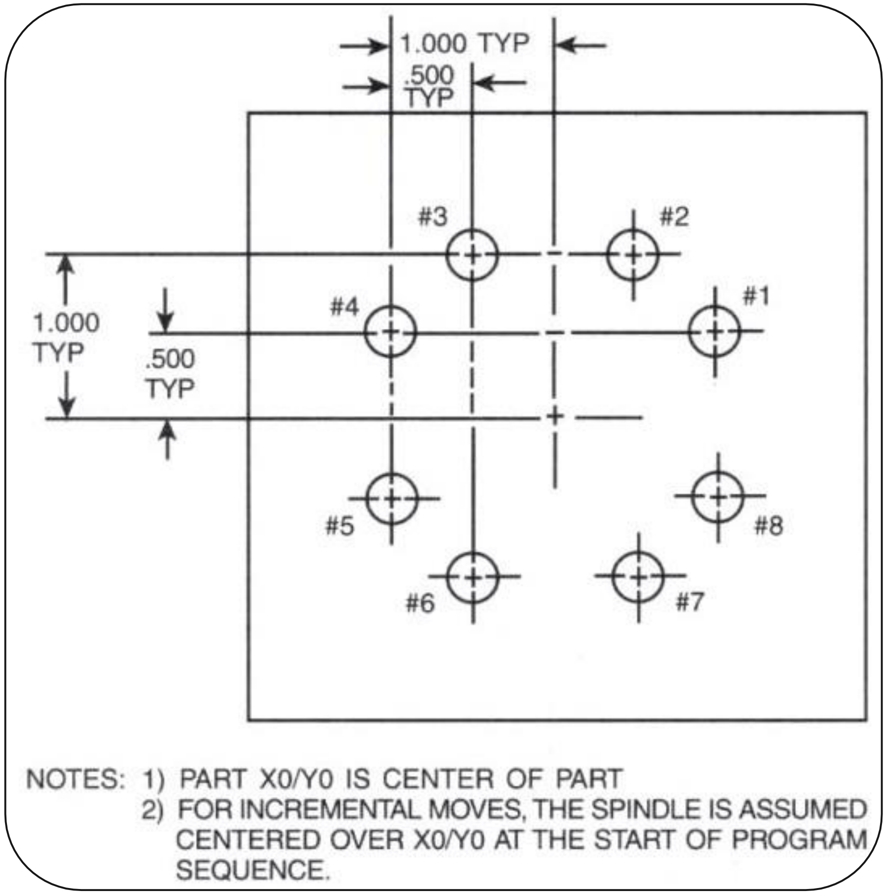


FIGURE 3: Part to be drilled

Absolute Positioning – Datum Dimensioning - ***Drilling***

- The holes on the part are to be drilled
- All positions on the part are taken from the (X0,Y0) point at the ***CENTER*** of the part
- Part is symmetric
- The signs of (X,Y) change as the coordinate locations move from quadrant to quadrant

Coordinates:

#1 X1.0000, Y0.5000	#5 X-1.0000, Y-0.5000
#2 X0.5000, Y1.0000	#6 X-0.5000, Y-1.0000
#3 X-0.5000, YI.0000	#7 X0.5000, Y-1.0000
#4 X-1.0000, Y0.500	#8 X1.0000, Y-0.5000

LAB Hole Operations Example

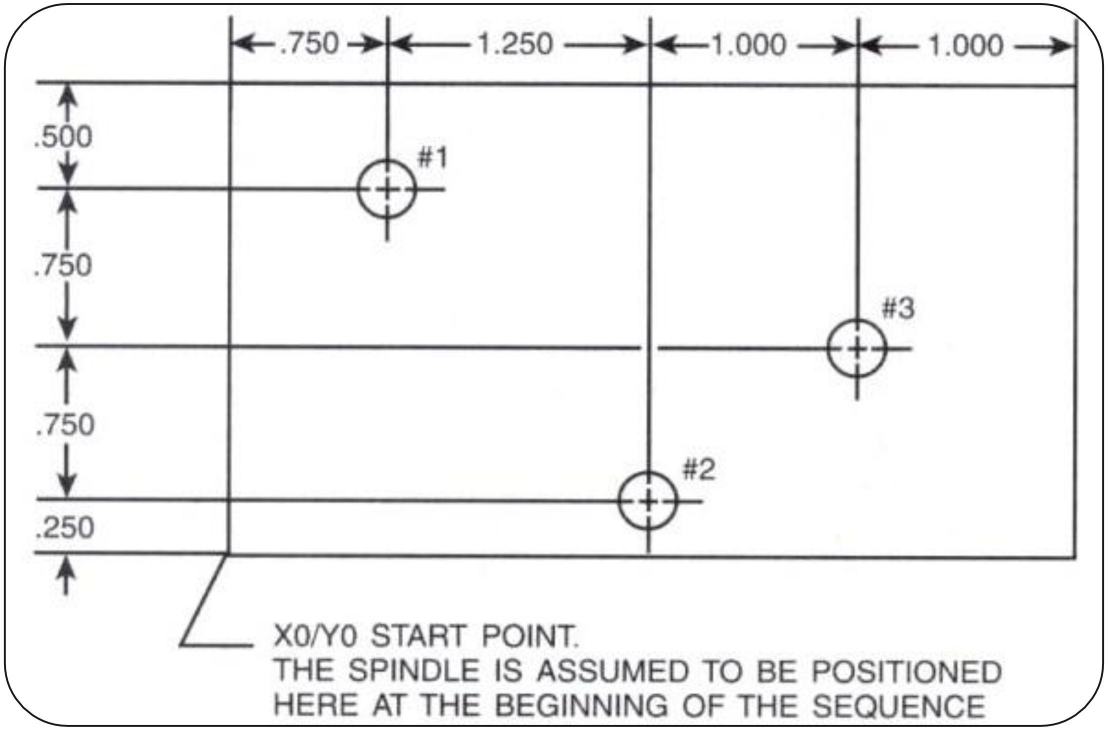


FIGURE 4 :Delta dimensioned part drawing

Coordinates:

#1 X0.7500, Y1.7500

#2 X1.2500, Y-1.5000

#3 X1.0000, Y0.7500

Incremental Positioning – Delta Dimensioning - Drilling

- The **holes** on the part are to be drilled
- All positions on the part are taken from the (X0, Y0) point at the lower left corner of the part
- If no sign given the machine will assume a **positive movement**

Hole Operations Example

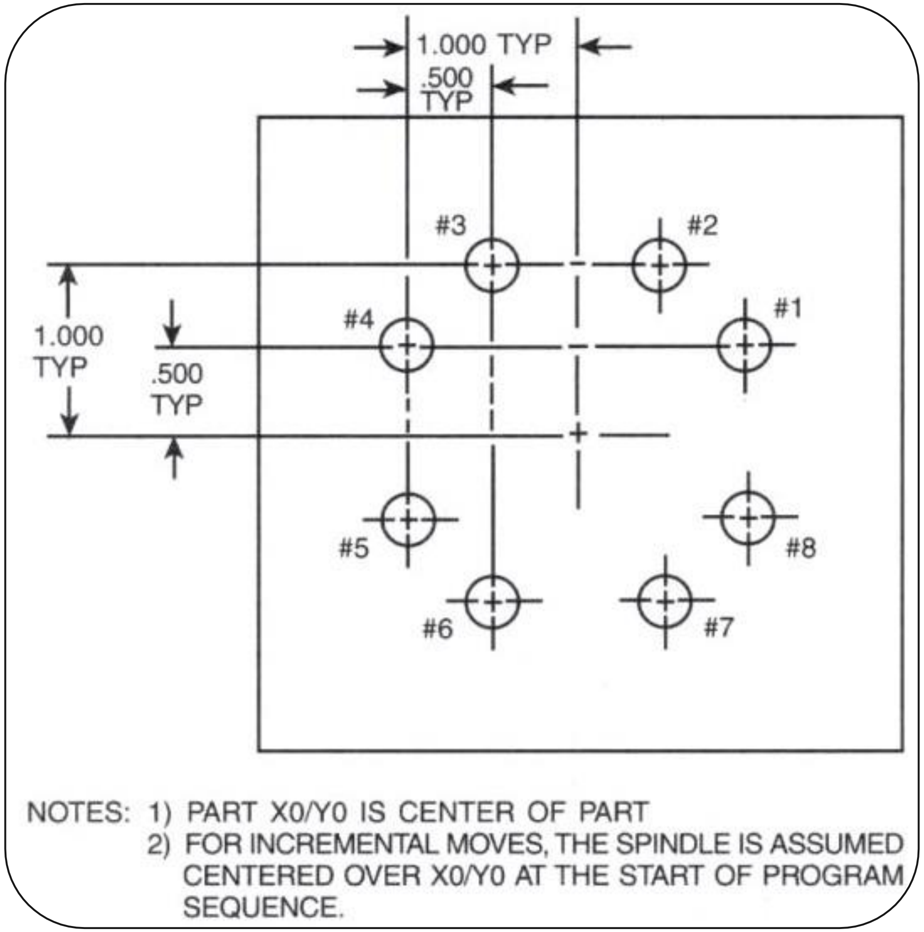


FIGURE 5: Part to be drilled

Incremental Positioning – Delta Dimensioning - *Drilling*

- The **holes** on the part are to be drilled
- All positions on the part are taken from the (X0,Y0) point at the ***CENTER*** of the part
- Part is **symmetric**
- The signs of (X,Y) change as the coordinate locations move from quadrant to quadrant

Coordinates:

#1 X1.0000, Y0,5000	#5 X0.0000, Y-1.0000
#2 X-0.5000, Y0.5000	#6 X0.5000, Y-0.5000
#3 X-1.0000, Y0.0000	#7 X1.0000, Y0.0000
#4 X-0.5000, Y-0.5000`	#8 X0.5000, Y0.5000

Milling Operations Example

MILLING Operations

- The system of coordinates presented thus far is used for centering a spindle over a particular location specified on a drawing

- This means that when a coordinate location is given to the machine the ***center of the spindle*** is sent to that location

Milling Cutters PROBLEM

- More than the correct amount of stock would be removed from the part

- This amount will be equal to the ***Radius of the Cutter***

SOLUTION

- When positioning the spindle for the milling operation an ***allowance*** must be made for the radius of the cutter

Milling Operations Example

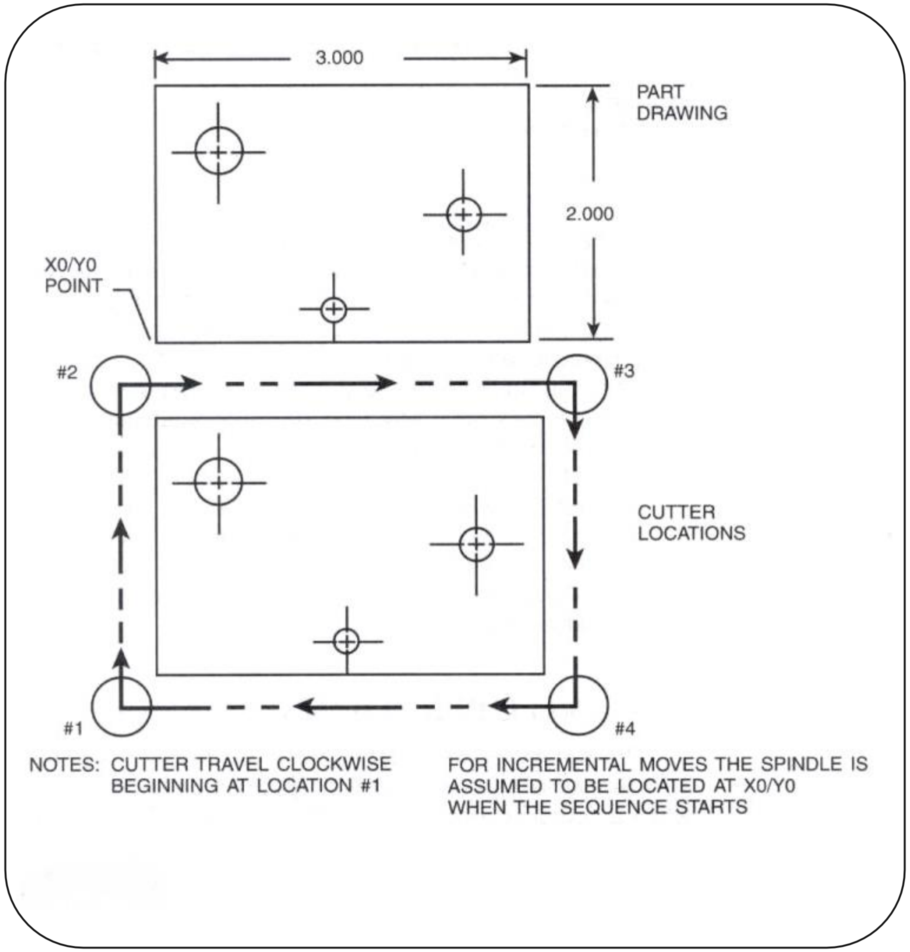


FIGURE 6: Part to be milled

- A 0.500-inch –diameter end mill will be used to mill the part of Fig.6
- All positions on the part are taken from the (X0,Y0) point at the *left down corner of the part*
- An *Absolute Positioning* mill will be used
- Sending the cutter to X0, Y0 to begin a milling pass from #1 to #2 will remove an additional 0.250 inch of metal from the part
- To allow for the radius of the cutter calculate the cutter coordinate by ***subtracting half the diameter of the cutter*** from the coordinate location in each axis

#1 X-0.2500, Y-0.2500

#2 X-0.2500, Y2.2500

#3 X3.2500, Y2.2500

#4 X3.2500, Y-0.2500

Milling Operations Example

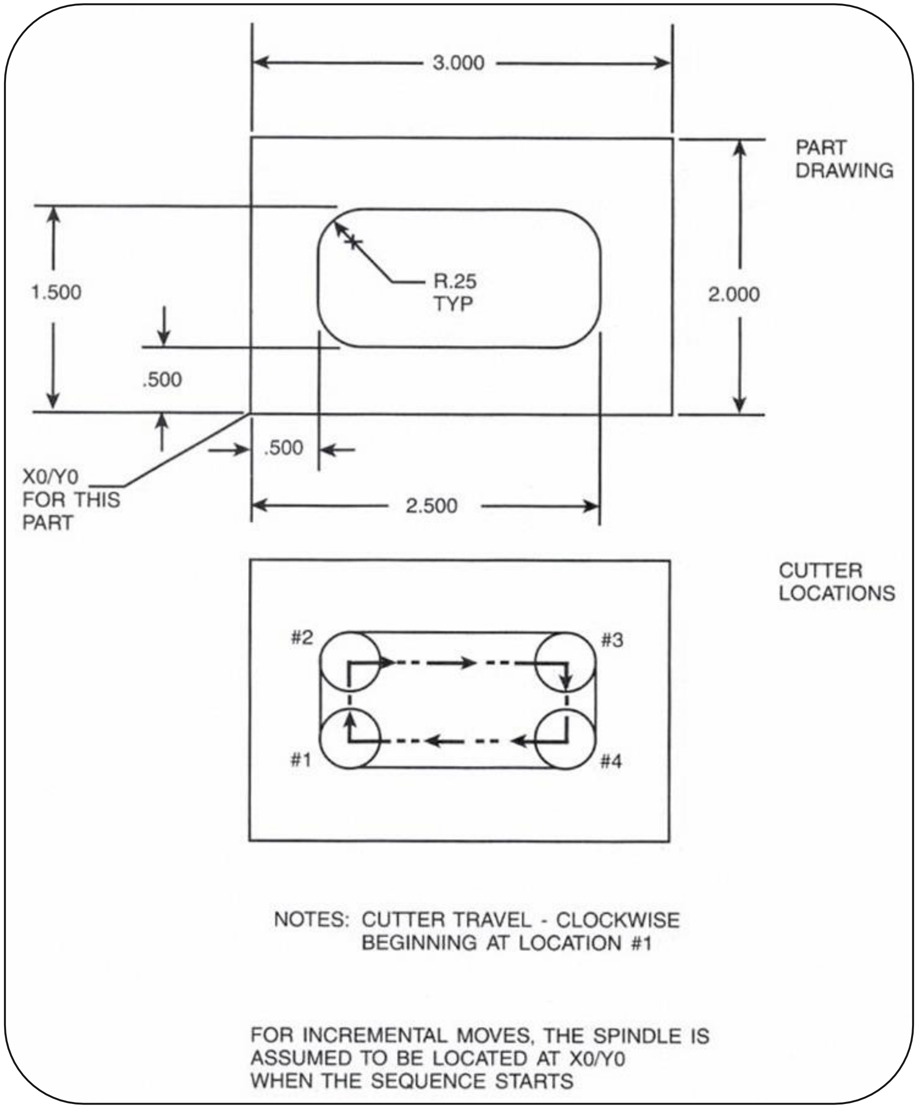


FIGURE 7: Part to be milled

- A 0.500-inch –diameter end mill will be used to mill the part of Fig.7
- All positions on the part are taken from the (X0,Y0) point at the ***left down corner of the part***
- An ***Absolute Positioning*** mill will be used
- A ***Datum Dimensioning*** system is used

Coordinates:

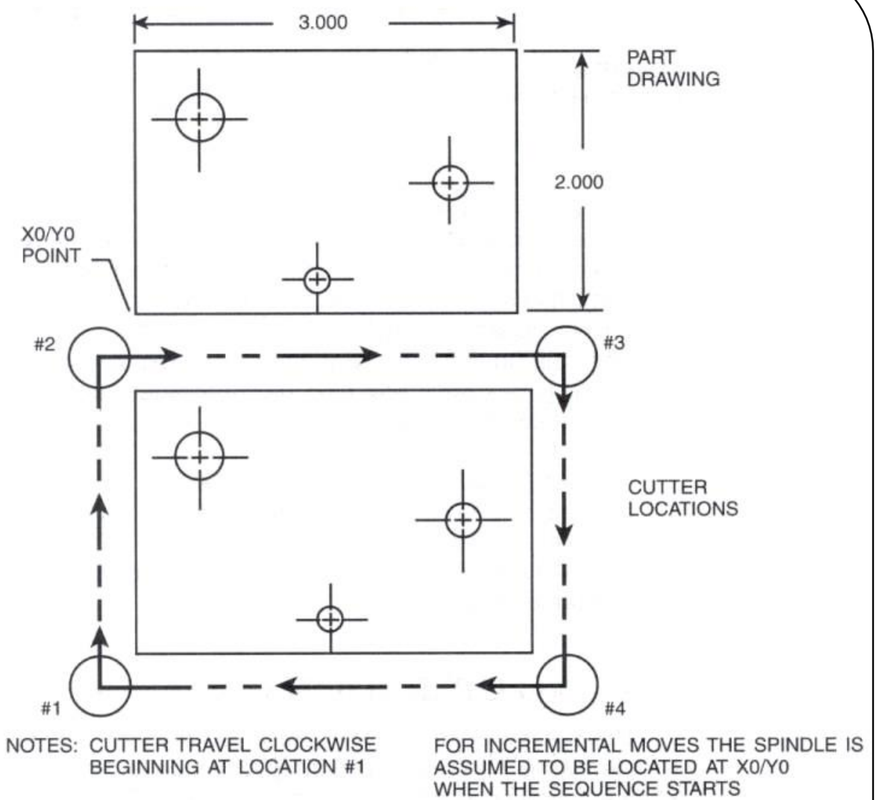
#1 X0.7500, Y0.7500

#2 X0.7500, Y1.2500

#3 X2.2500, Y1.2500

#4 X2.2500, Y0.7500

Milling Operations Example



- A 0.500-inch –diameter end mill will be used to mill the part of Fig.8
- On each position (# j) on the part is located the (X0,Y0) point
- An ***Incremental Positioning*** mill will be used
- A ***Datum Dimensioning*** system is used

Coordinates:

#1 X-0.2500, Y-0.2500

#2 X0.0000, Y2.5000

#3 X3.5000, Y0.0000

#4 X0.0000, Y-2.5000

FIGURE 8: Part to be milled

Milling Operations Example

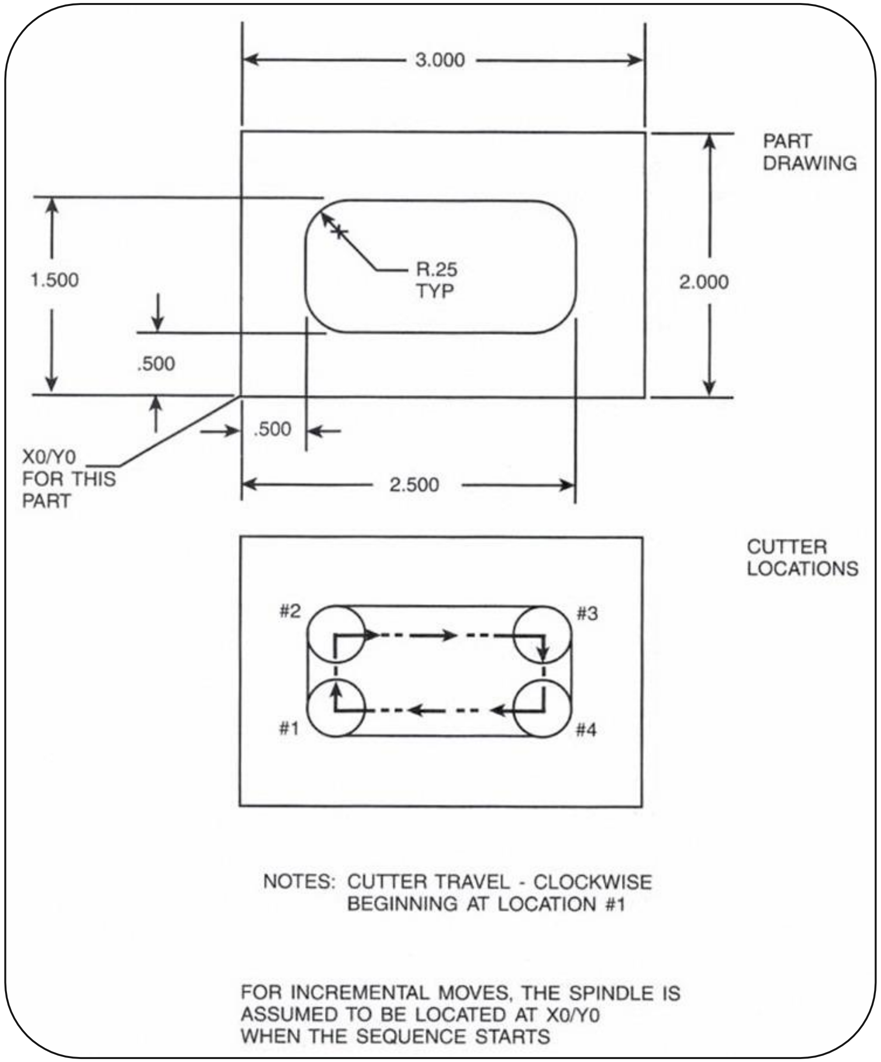


FIGURE 9: Part to be milled

- A 0.500-inch –diameter end mill will be used to mill the part of Fig.9
- On each position (# j) on the part is located the (X0,Y0) point
- An ***Incremental Positioning*** mill will be used
- A ***Datum Dimensioning*** system is used

Coordinates:

#1 X0.7500, Y0.7500

#2 X0.0000, Y0.5000

#3 X1.5000, Y0.0000

#4 X0.0000, Y-0.5000

Mixing Absolute and Incremental Positioning

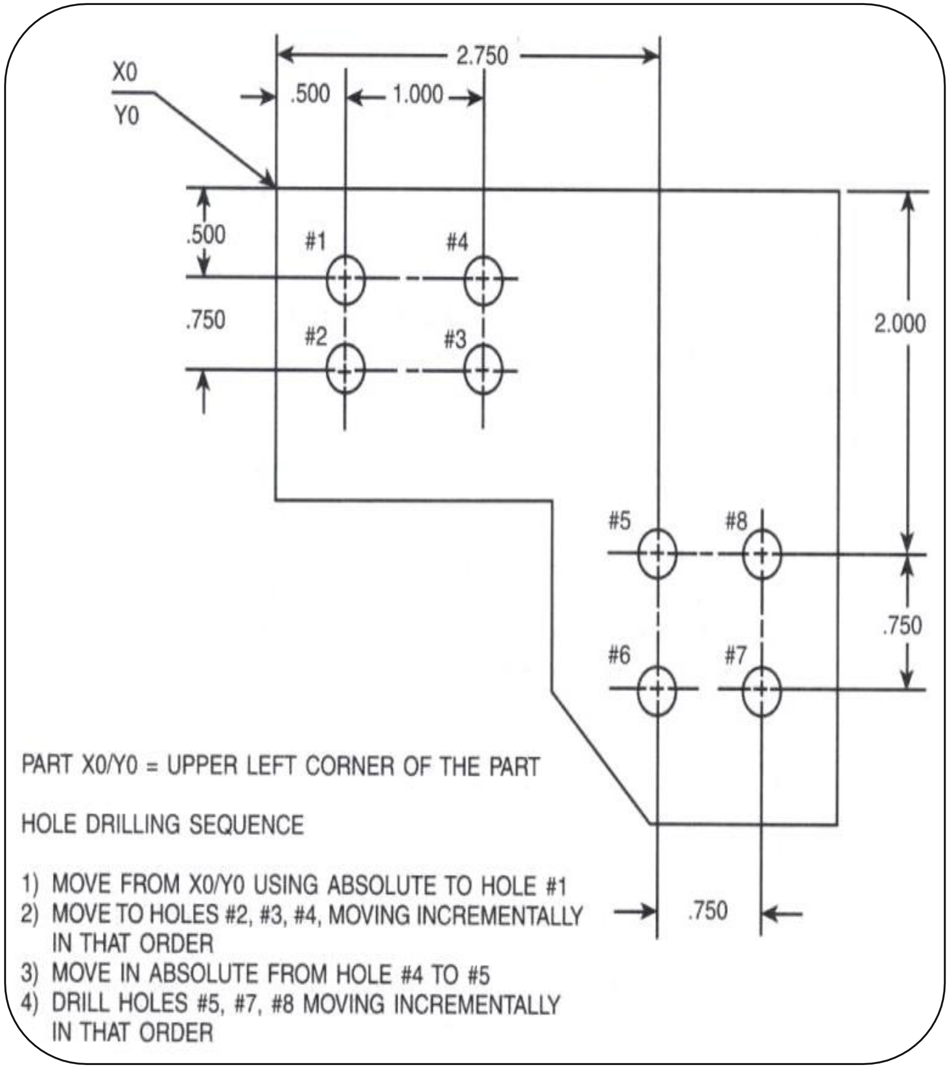


FIGURE 10:Part to be drilled that combines Absolute & Incremental Positioning

Mixing Absolute and Incremental Positioning

- Great flexibility in programming parts

Drilling Example:

- #1: Absolute Positioning
- #2, #3, #4: Incremental
- #5: Absolute
- #6, #7, #8: Incremental

Coordinates:

#1 X0.5000, Y-0,5000	#5 X2.7500, Y-2.0000
#2 X0.0000, Y-0.7500	#6 X0.0000, Y-0.7500
#3 X1.0000, Y0.0000	#7 X0.7500, Y0.0000
#4 X0.0000, Y0.7500	#8 X0.0000, Y0.7500

Summary

- To program a **hole location coordinate**, the **center line** for the hole is used
- To program a coordinate for milling operations, the coordinate for the location must include an appropriate **allowance for the radius** of the cutter
- For **absolute positioning** , the datum reference plane remains the X0, Y0 point for all programmed moves
- For **incremental positioning**, the current coordinate location is the X0, Y0 point for the next move
- CNC machines are capable of **mixing absolute and incremental positioning**. This allows for flexibility in programming
- Metric measurement in the machine shop is based on the millimetre, where: 0.02mm is roughly equivalent to 0.001inch
- To **convert** an inch dimension to millimetres, **multiply the inch dimension by 25.4**
- To **convert** a metric dimension to inches, **multiply the metric dimension by 0.03937**, or
- Divide the **metric dimension by 25.4**

References

1. Ann Mazakas, Manager of Technical Communications, DP Technology, ‘’The Art of Automation’’, courses materials of ESPTRIT World Conference on CNC
2. Chryssolouris G., «Manufacturing Systems: Theory and Practice», 2nd Edition, 2006, Springer-Verlag
3. http://www.dptechnology.com/
4. http://www.custompartnet.com/
5. http://www.sandvik.coromant.com/
6. Kalpakjian S., «Manufacturing Engineering and Technology», 2nd Edition, 1992, Addison-Wesley Publishing company
7. Mattson M., “CNC Programming, Principles and Applications”, Delmar, 2002
8. Moriwaki T., “Multi-Functional Machine Tool”, CIRP Annals Manufacturing Technology, Vol. 57/2, 2008, pp. 736-749
9. Seams W., “Computer Numerical Control, Concepts & Programming”, 4th Edition, Delmar, 2002
10. Γ. Χρυσολούρης, «Συστήματα Παραγωγής Θεωρία και Πράξη» Μέρος I και II, Εκπαιδευτικές Σημειώσεις, Πανεπιστήμιο Πατρών, 2001,

References

11. Γ. Χρυσολούρης, Δ. Μούρτζης, Κ. Τσίρμπας, Σ. Καραγιάννης, “Ορθογωνική Κοπή”, Εκπαιδευτικές Σημειώσεις, Πανεπιστήμιο Πατρών, 2000
12. Γ. Χρυσολούρης, Δ. Μούρτζης, και άλλοι, “Εργαστήρια Μηχανουργικής Τεχνολογίας Ι και ΙΙ”», Εκπαιδευτικές Σημειώσεις για το εργαστήριο του αντιστοίχου μαθήματος, Πανεπιστήμιο Πατρών, 2008 (4η Έκδοση)
13. Δ. Μούρτζης, “Αριθμητικός Έλεγχος Εργαλειομηχανών” Εκπαιδευτικές Σημειώσεις, Πανεπιστήμιο Πατρών, 2011 (3η Έκδοση)
14. Πετρόπουλου Π.Γ., «Μηχανουργική Τεχνολογία – ΙΙ. Τεχνολογία κατεργασιών κοπής των μετάλλων», 1998, Εκδόσεις Ζήτη
15. Σύγχρονες μέθοδοι κατεργασίας υλικών και προγραμματισμός με Ηλεκτρονικό Υπολογιστή (Η/Υ) ,Δ. Μούρτζης ,Κ. Σαλωνίτης