



INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad – 500043

COURSE CONTENT

COMPUTER AIDED MANUFACTURING (CAM) LABORATORY								
VI Semester: AE								
Course Code	Category	Hours / Week			Credits	Maximum Marks		
AAEC33	Core	L	T	P	C	CIA	SEE	Total
		-	-	3	1.5	30	70	100
Contact Classes: Nil	Tutorial Classes: Nil	Practical Classes: 45			Total Classes: 45			
Prerequisite: Mechanics of Solids								

I. COURSE OVERVIEW:

Computer-aided manufacturing (CAM) is a technique that uses computer software and hardware to optimize and automate processes in manufacturing. This laboratory course provides learners with real skills and experience with computer-aided tools in manufacturing processes. The course includes topics such as computer numerical control (CNC) equipment, component identification, safety measures, setting up of home locations, offsets, part programming using G Codes, program execution, dimensional accuracy, and surface finish. It will combine theoretical understanding with hands-on applications in a modern learning environment.

II. COURSES OBJECTIVES:

The students will try to learn:

- I. The fundamental principles of computer-aided manufacturing and the integration of computer technology into manufacturing processes.
- II. The workflow from design to production using CAM tools, and become proficient in utilizing industry-standard CAM for manufacturing operations.
- III. Real-world involvement with Computer Numerical Control (CNC) machines through programming and operating CNC milling and turning machines.
- IV. Toolpath optimization strategies to perform efficient machining to improve production time and enhance tool life.

III. COURSE OUTCOMES:

After successful completion of the course, students should be able to:

- CO1 Outline various computer numeric control systems for suitability and application on CNC machines.
- CO2 Recognize various standard machine tools and numeric codes for manufacturing machine parts by turning machines.
- CO3 Develop a numeric code for manufacturing machine components by milling machine.
- CO4 Make use of G and M codes for drilling operation on machine components using milling machine.
- CO5 Investigate tapping, slotting and cylindrical grinding by using CNC for manufacturing aircraft components.
- CO6 Utilize laser cutting and electric discharge machine for cutting and drilling of airfoil profile.

IV. COURSE CONTENT

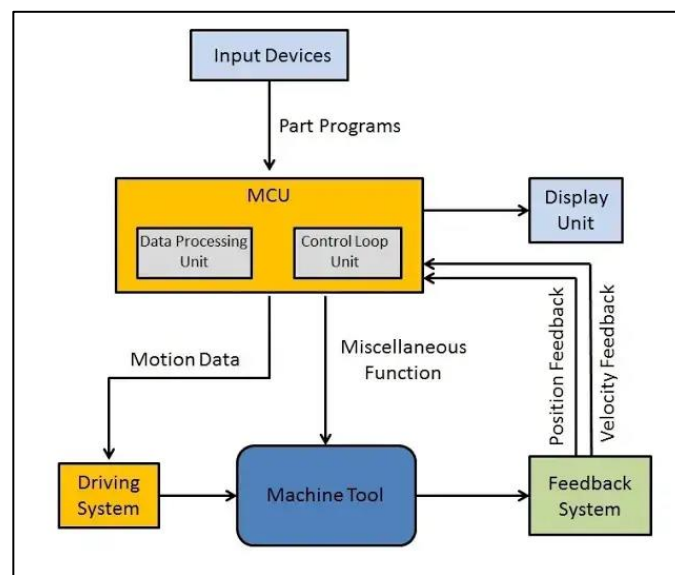
Exercises For Computer Aided Manufacturing (CAM) Laboratory

1.Introduction

1.1. Computer Numeric Control

Computer Numerical Control (CNC) is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data. CNC can control the motions of the work piece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning spindle on/off, turning coolant on/off. CNC is the automation of machine tools that are operated by precisely programmed commands encoded on a storage medium.

A CNC system consists of three basic components (Figure 1): Part program, Machine Control



Unit (MCU) and Machine tool (lathe, drill press, milling machine etc.).

Figure 1: Basic Components of CNC System.

1.2 FANUC System

A FANUC CNC Machine control panel is shown in figure 2. The key aspects related to FANUC CNC are CNC Controller, Axis Drives, Servo Motors and Operator Panel and features of FANUC CNC Systems are Open Architecture, High-Speed and Precision, Reliability, Customization and Integration, Diagnostic and Maintenance Tools and PMC (Programmable Machine Controller). The FANUC CNC system also supports using standard G-code and M-code programming language, Manual Data Input (MDI), Custom Macro B and High-Level Programming Languages such as FANUC's own APT (Automatically Programmed Tool) language.

2.2 CNC Facing Operation on Mill

Develop a Numeric code to perform a Face milling on a rectangular block given figure 5 to get flat face to on a CNC Mill machine.

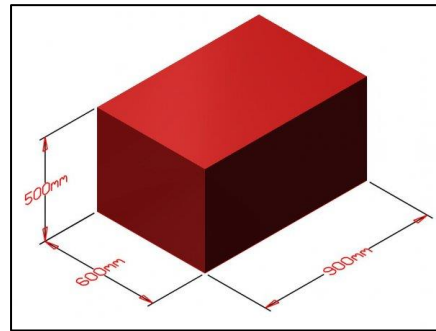


Figure 5: Final Job of the Block.

Hints

```
O1221;                                     \\ Program name
N01 G40 G21 G99 G90;                       \\ Machine Setup
N02 G28 U0.0 W0.0;                         \\ Machine home reference return
N03 M06 T0101;                             \\ Tool Selection
N04 M03 S1000;                             \\ Spindle ON with 1000 RPM speed.
N05 G00 X-100.0 Y0.0 Z5.0;
N06 G01 X1000.0 Y30.0 Z-1.5 F2.0;          \\ Facing operation with 2 mm/min F.R
N07 G01 Y60.0;
. . . . .
N15 G01 X35.0 Z2.0;
N16 G00 U0.0 W0.0;                         \\ Machine tool to machine home
position
N17 M05 ;                                  \\ Spindle OFF
N18 M30;                                   \\ Program End and reset to start.
```

Try

1. Rewrite the developed NC code to reduce the cycle time per job using canned cycles.
2. Develop a 3D model of the job and generate an automated numeric code with operations in MasterCAM software.

3. Exercises on Plain Turning

3.1 Develop a Numeric code to perform a turning operation on a cylindrical block to get a job as given in figure 7 on a CNC lathe machine. Use spindle speed of 1000 RPM and feed rate of 2mm/min.

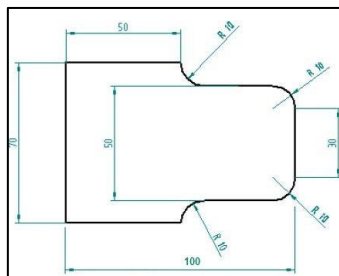


Figure 7: Final Job Shape of the block.

Try

1. Modify the NC code to reduce the cycle time per job using canned cycles namely, G70 and G71.
2. Develop a 3D model of the job and generate an automated numeric code in Mastercam software.

4. Exercises on Step Turning

4.1 Write a Numeric code to perform a step turning operation on a cylindrical block to get a job as given in below figure 9 on a CNC lathe machine. Use spindle speed of 1000 RPM and feed rate of 2mm/min.

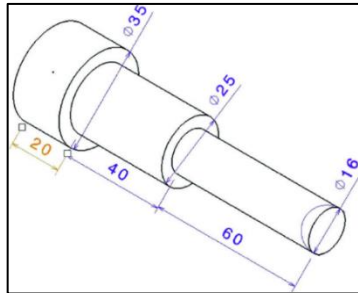


Figure 9: Final Shape of the job

Hints

```
O1321;                                     \\ Program name
N01 G40 G21 G99 G90;                       \\ Machine Setup
N02 G28 U0.0 W0.0;                         \\ Machine home reference return
N03 M06 T0101 M08;                         \\ Tool Selection and Flood Coolant
ON                                          ON
N04 M03 S1000;                             \\ Spindle ON with 1000 RPM speed.
N05 G00 X37.5 Z5.0;
N06 G01 X35.0 Z0.0 F2.0;                   \\ Turning operation with 2 mm/min
N07 G01 Z-100.0;                           F.R
. . . . .
N15 G01 X35.0 Z2.0;
N16 G00 U0.0 W0.0;                         \\ Machine tool to machine home
position
N17 M05 M09;                               \\ Spindle and Coolant OFF
N18 M30;                                   \\ Program End and reset to start.
```

4.2 Create a Numeric code to perform a step turning operation to get a job as given in below figure 10 on a CNC lathe machine.

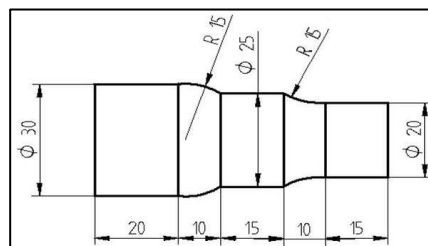


Figure 10: Final profile of the job.

Hints

```
O1121;                \\ Program name
N01 G40 G21 G99 G90;  \\ Machine Setup
N02 G28 U0.0 W0.0;   \\ Machine home reference return
N03 M06 T0303 M08;   \\ Tool Selection and Flood Coolant
ON
N04 M03 S8000;        \\ Spindle ON with 800 RPM speed.
N05 G00 X32.5 Z5.0;
N06 G01 X30.0 Z0.0 F2.0;
N07 G01 Z-70.0;      \\ Turning operation with 2 mm/min
F.R
. . . . .
N15 G01 X32.5 Z2.0;
N16 G00 U0.0 W0.0;   \\ Machine tool to machine home
position
N17 M05 M09;         \\ Spindle and Coolant OFF
N18 M30;             \\ Program End and reset to start.
```

Try

1. Modify the NC code to reduce the cycle time per job using canned cycles namely, G70 and G71.
2. Develop a 3D model of the job and generate an automated numeric code in MasterCAM software by specifying machining parameters.

5. Exercises on Grooving and Threading

5.1 Grooving

Develop a Numeric code to create a circular groove on a cylindrical job shown in figure 11 on a CNC lathe machine.

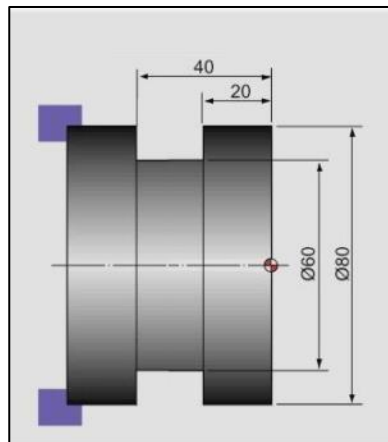


Figure 11: Groove on a job.

Hints

```
O1321;                \\ Program name
N01 G40 G21 G99 G90;  \\ Machine Setup
N02 G28 U0.0 W0.0;   \\ Machine home reference return
N03 M06 T0505;       \\ Tool Selection-Groove tool
N04 M03 S500;        \\ Spindle ON with 500 RPM speed.
N05 G00 X82.5 Z5.0;
N06 G01 X80.0 Z20.0 F2.0;
N07 G01 Z-100.0;     \\ Grooving operation with 2 mm/min
F.R
```

```

. . . . .
N15 G01 X82.5 Z-40.0;
N16 G00 U0.0 W0.0;           \\ Machine tool to machine home
                             position
N17 M05 M09;                \\ Spindle and Coolant OFF
N18 M01;                     \\ Program stop

```

Try

1. Alter the above NC code using canned cycles namely G75 to reduce the overall cycle time on the job,
2. Generate an automated code in MasterCAM software by specifying Groove parameters.

5.2 Threading

Create a Thread of M20 x1.5 on a cylindrical bar upto 18mm as shown in figure 12 from one end of the stock.

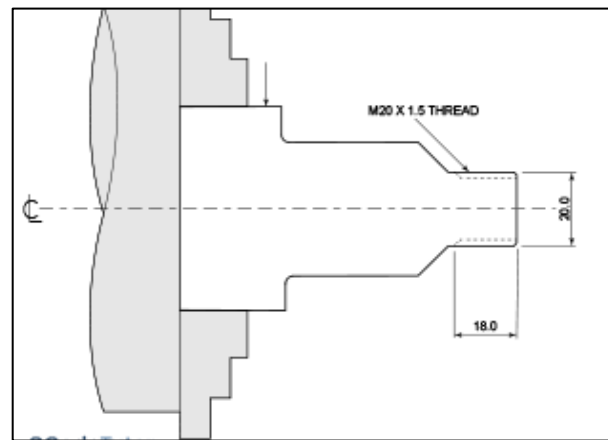


Figure 12: M20 x 1.5 Thread on a job.

Hints

```

O1421;                       \\ Program name
N01 G40 G21 G99 G90;         \\ Machine Setup
N02 G28 U0.0 W0.0;          \\ Machine home reference return
N03 M06 T0505;              \\ Tool Selection-Groove tool
N04 M03 S500;               \\ Spindle ON with 500 RPM speed.
N05 G00 X22.5 Z5.0;
N06 G01 X20.0 Z0.0 F2.0;
N07 G76 X18.2 Z-18.0 I-.01 K900 D100 F1.5; \\ Threading operation (M20 x 1.5)
N08 G00 X25.0 Z10.0;
N09 G00 U0.0 W0.0;         \\ Machine tool to machine home
                             position
N10 M05 M09;                \\ Spindle and Coolant OFF
N11 M01;                     \\ Program stop

```

Try

1. Alter the above NC code to use double line G76 screw thread cycle.
2. Generate an ACME Thread for the same.

6. Exercises on Drilling and Boring

6.1 Drilling

Drill a hole till 24 mm with 12 mm diameter on a cylindrical job centrally on a face using CNC lathe machine as shown in figure 13.

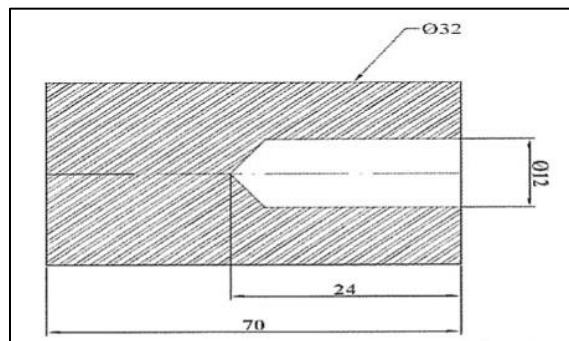


Figure 13: Drilling Operation

Hints

```
O1461;                                \\ Program name
N01 G40 G21 G99 G90;                   \\ Machine Setup
N02 G28 U0.0 W0.0;                     \\ Machine home reference return
N03 M06 T0606;                          \\ Tool Selection-Drill tool
N04 M03 S200;                            \\ Spindle ON with 200 RPM speed.
N05 G00 X35.0 Z5.0;
N06 G01 X0.0 Z2.0 F1.0;
N07 G01 Z-24.0;                          \\ Drilling operation (24mm depth)
N08 G01 Z10.0;
N09 G00 U0.0 W0.0;                       \\ Machine tool to machine home
position
N10 M05 M09;                             \\ Spindle and Coolant OFF
N11 M01;                                 \\ Program stop
```

Try

1. Alter the above NC code using canned cycles namely G74 and G83 to improve the quality of drilled hole.
2. Generate an automated code in MasterCAM software by specifying hole parameters.

6.2 Boring

Develop a Numeric code to enlarge a hole of 35 mm to 40 mm on a CNC lathe machine as shown in figure 14.

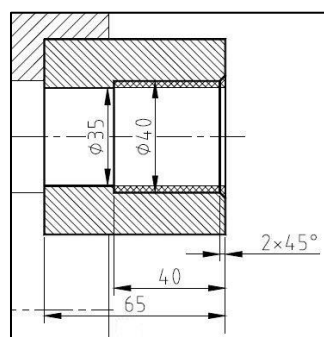


Figure 14: Boring operation of the job.

Hints

```
O1461;           \\ Program name
N01 G40 G21 G99 G90; \\ Machine Setup
N02 G28 U0.0 W0.0; \\ Machine home reference return
N03 M06 T0101;    \\ Tool Selection-Boring Tool
N04 M03 S800;     \\ Spindle ON with 800 RPM speed.
N05 G00 X41.0 Z0.0;
N06 G01 X40.0 Z1.0 F1.0;
N07 G01 Z-40.0;   \\ Boring operation
N08 G01 X30.0 Z10.0;
N09 G00 U0.0 W0.0; \\ Machine tool to machine home
position
N10 M05 M09;     \\ Spindle and Coolant OFF
N11 M30;         \\ Program stop
```

Try

1. Modify the above NC code using canned cycles namely G71 and G70 to improve the cycle time and finish of the operation.
2. Generate an automated numeric code in MasterCAM software for boring operation on CNC lathe.

7. Exercises on Milling: Plain and Step Milling

7.1. Plain Milling

Generate a NC code to remove 8mm of top surface of the rectangular block of 200 x120 mm as shown in figure 15.

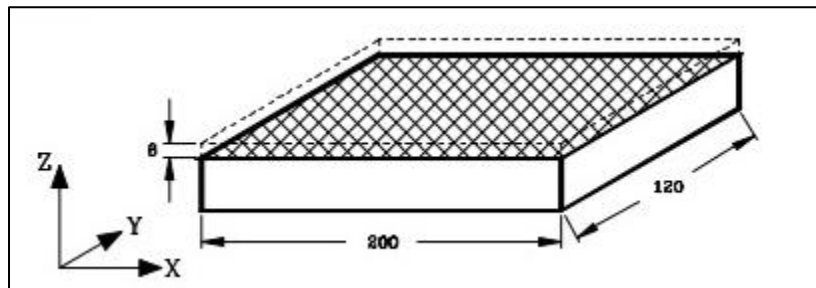


Figure 15: Plain milling on the job.

Hints

```
O2356;
N01 F200 S800 M03 M41;
N02 G90 X-50.0 Y0.0 Z25.0;
N03 G01 Z8.0 F200;
N04 G01 G90 X-30.0 Y0.0 F250.0;
N05 G05 G01 Z-2.0 F200.0;
. ....
N13 G01 Z20.0;
N14 G00 X-50.0;
N15 M30;
```

7.2. Step Milling

Develop a NC code to create a pocket of 15mm depth from the top surface on the rectangular block of 160 x160 x 20 mm of shape as shown in figure 16 with 5mm as depth of cut.

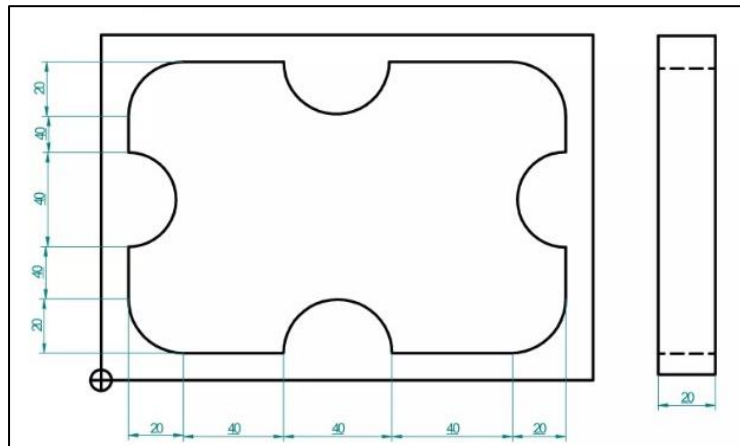


Figure 16: Plain milling on the job.

Hints

```
O2356;  
N01 F500 S800 M03 M41;  
N02 G90 X-50.0 Y0.0 Z25.0;  
N03 G01 Z8.0 F200;  
N04 G01 G90 X-30.0 Y0.0 F250.0;  
N05 G05 G01 Z-2.0 F200.0;  
.  
.  
.  
.  
.  
.  
N12 G01 X-30.0;  
N13 G01 Z20.0;  
N14 G00 X-50.0;  
N15 M30;
```

Try

1. An improved code for the plain and step operations using subroutine cycles.
2. Generate an automated code in MasterCAM to optimize the final finish of the pocket.

8. Exercises on Drilling operation on VMC

8.1 Develop a Numeric code to create a hole of 5 mm diameter at various positions given below in figure 17.

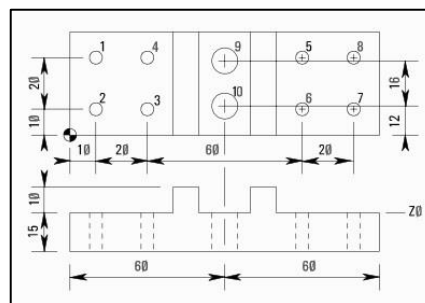


Figure 17: Drilling operation on the job.

Hints

```
O1451;                                \\ Program name
N01 G40 G21 G99 G90;                  \\ Machine Setup
N02 G28 U0.0 W0.0;                    \\ Machine home reference return
N03 M06 T0505;                         \\ Tool Selection-Drill Tool 5 mm Dia.
N20 G00 X10.0 Y30.0 Z12.0 S1000 M03;  \\ Drill tool Positioning at hole.
N30 G81 X10.0 Y30.0 Z-17.0 R2.0 F75.0 \\ Drilling operation at Hole 1
N40 Y10.0                               (Hole 2)
. . . . .
N120 G83 X60.0 Y28.0 Z-17.0 Q6 R2.0 F60.0; (Hole 9)
N150 G98 Y12.0;                        (Hole 10)
N160 G91 G80 G28 X0.0 Y0.0 Z0.0 M05;   \\ Machine home position and Spindle
OFF                                     OFF
N170 M30;
```

8.2 Generate a Numeric code to create a hole of M5x1.25 diameter at positions given below in figure 18.

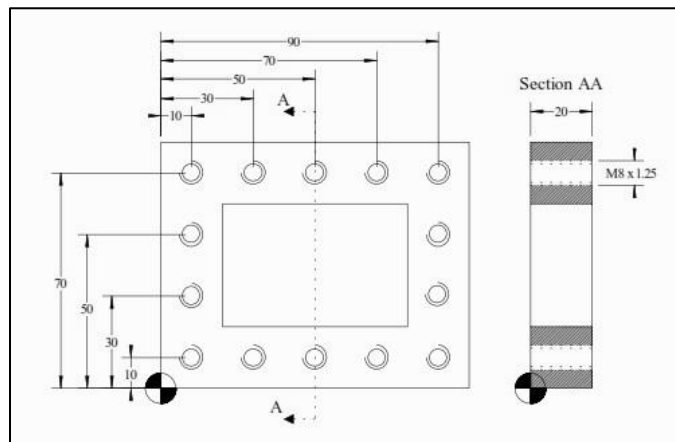


Figure 18: Drilling operation on the job.

Hints

```
O1451;                                \\ Program name
N01 G40 G21 G99 G90;                  \\ Machine Setup
N02 G28 U0.0 W0.0;                    \\ Machine home reference return
N03 M06 T0505;                         \\ Tool Selection-Drill Tool 5 mm Dia.
N20 G00 X10.0 Y30.0 Z12.0 S1000 M03;  \\ Drill tool Positioning at hole.
N30 G81 X10.0 Y30.0 Z-17.0 R2.0 F75.0 \\ Drilling operation at Hole 1
. . . . .
N110 G91 G80 G28 X0.0 Y0.0 Z0.0 M05
N120 G83 X60.0 Y28.0 Z-17.0 Q6 R2.0 F60.0; (Hole 9)
N150 G98 Y12.0;                        (Hole 10)
N160 G91 G80 G28 X0.0 Y0.0 Z0.0 M05;   \\ Machine home position and Spindle
OFF                                     OFF
N170 M30;
```

Try

1. Modify the above code with peck drilling code namely G83 for creating better hole finish.
2. Develop the numeric code on MasterCAM for drilling on milling machine.


```

N15 G00 Z5.0 M09;           \\ Coolant OFF
N16 G53 X0.0 Y0.0 Z0.0 M05; \\ Machine home and Spindle OFF
N17 G40 M01;                \\ Program End.

```

Try

1. Create an effective code to reduce machining time using Canned cycles.
2. Generate an automated code using MasterCAM and check for machine finish.

10. Exercises on Tapping and Slotting

10.1 Tapping Operation

Create a thread of M12x1.5 on drilled hole of diameter 10 mm by tapping operation on VMC.

Hints

```

O1461;                       \\ Program name
N01 G40 G21 G99 G90;         \\ Machine Setup
N02 G28 U0.0 W0.0;          \\ Machine home reference return
N03 M06 T0101;              \\ Tool Selection-Tap M12x1.5
N04 M03 S100;               \\ Spindle ON with 100 RPM speed.
N05 G00 X25.0 Y25.0 Z5.0;
N06 G01 Z-5.0 F1.0;
N07 G01 Z5.0;                \\ Tapping operation
N08 G01 X0.0 Y0.0;
N09 G00 U0.0 W0.0;          \\ Tool to machine home position
N10 M05 M09;                \\ Spindle and Coolant OFF
N11 M30

```

Try

1. Perform the Multiple tapping operations using G84 code and also use other forms of G84 also.
2. Generate an automated code for tapping operation on MasterCAM.

10.2 Slotting Operation

Create a rectangular slot of 10 x 10 mm on a stock by VMC.

Hints

```

O1641;                       \\ Program name
N01 G40 G21 G99 G90;         \\ Machine Setup
N02 G28 U0.0 W0.0;          \\ Machine home reference return
N03 M06 T0101 M06;          \\ Tool Selection- End mill of 10mm
N04 M03 S800;               \\ Spindle ON with 800 RPM speed.
N05 G00 X50.0 Y25.0 Z10.0;
N06 G01 Z-1.0 F1.0;
N07 G01 X125.0;              \\ Slotting operation
N08 .....
N29 G01 X50.0 Y25.0 Z10.0;
N30 G00 U0.0 W0.0;          \\ Tool to machine home position
N31 M05 M09;                \\ Spindle and Coolant OFF
N32 M30;                    \\ Program End.

```

Try

1. Repeat the above program with changing the shape of the cutter and observe the type of slot formed after machining.
2. Optimize the above code to reduce overall machining time for slotting operation.
3. Generate an automated code using MasterCAM for Slotting operation.

11. Exercises on CNC Cylindrical Grinding.

11.1 Perform cylindrical grinding operation using CNC cylindrical grinding machine on a solid cylindrical bar stock.

Hints

- Mount the cylindrical stock on to the grinding wheel between two roller supports.
- Switch ON the machine and set the machining workspace and parameters for the job.
- Set the grinding depth and number of steps to be performed along the cylindrical stock to get the desired diameter.
- Start grinding process by turning the stock constantly around itself to get consistent results.
- Upon the desired result of the stock, switch off the machine and unmount the cylindrical stock.

11.2 Operate CNC cylindrical grinding machine to reduce an outer dimension of cylindrical block by 0.05mm.

Hints

- Mount the cylindrical stock on to the grinding wheel between two roller supports.
- Switch ON the machine and set the machining workspace and parameters for the job.
- Set the grinding depth and number of steps to be performed along the cylindrical stock to get the desired diameter.
- Start grinding process by turning the stock constantly around itself to get consistent results.
- Upon the desired result of the stock, switch off the machine and unmount the cylindrical stock.

Try

1. Repeat the same with higher grinding depths.
2. Perform cylindrical grinding on tapered bar to improve surface finish.

12. Exercise on Laser Cutting

12.1 Create aero foil profile cutting using Laser cutting machine.

Hints

- Import the aero foil coordinates that needs to be cut on the laser machine.
- Setup the laser machine foe cutting paths by selecting appropriate power for laser and speed of movement of the laser.
- Enclose the shape in a bounding box to ensure the material placement in this case balsa wood is in correct cutting path of the laser.
- If all checks out, then send the file to laser cutter to perform cutting.
- Let the machine complete the cutting cycle to give out a clean-cut part in aero foil shape.

12.2 Engrave a photograph onto balsa wood using Laser cutting machine.

Hints

- Import the aero foil coordinates that needs to be cut on the laser machine.
- Setup the laser machine foe cutting paths by selecting appropriate power for laser and speed of movement of the laser.
- Enclose the shape in a bounding box to ensure the material placement in this case balsa wood is in correct cutting path of the laser.
- If all checks out, then send the file to laser cutter to perform cutting.
- Let the machine complete the cutting cycle to give out a clean-cut part in aero foil shape.

Try

1. Repeat above exercise with any other aero profile shape for cutting on balsa wood.
2. Engrave a photograph on acrylic sheet using appropriate parameters.

13. Exercise on Rapid Drilling

13.1 Perform rapid drilling on a plate of diameter 10mm using Electrical Discharge machine.

Hints

- Switch on EDM Machine and make sure that it has sufficient dielectric liquid for the machining process to begin.
- Secure the job onto the clamps inside.
- Position the electrode and setup its work area on the job.
- Run the machine to perform the drilling of required diameter onto the job.
- After operation is complete, switch off the machine to take the job out.

13.2 Create a hole of diameter 10.35 mm using Electrical Discharge machine.

Hints

- Switch on EDM Machine and make sure that it has sufficient dielectric liquid for the machining process to begin.
- Secure the job onto the clamps inside.

- Position the electrode and setup its work area on the job.
- Run the machine to perform the drilling of required diameter onto the job.
- After operation is complete, switch off the machine to take the job out.

Try

1. Repeat the above experiment with variable diameter hole.
2. To use the EDM machine to create a part at most precision.

14. Additional Exercises

14.1 To Utilize the previously mentioned CNC operations to get final part made as shown in figure 20.

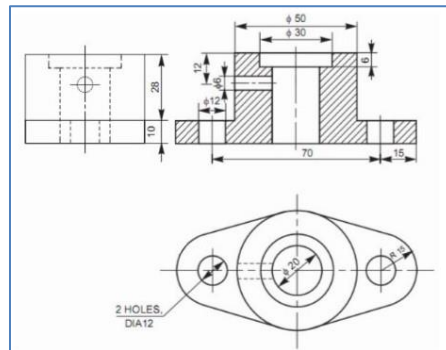


Figure 20: 2D Layout of the part.

Hints (Procedure to generate the code for part)

- Take a stock of 50 mm diameter x 50 mm for creating of part.
- Use CNC Lathe to perform facing and step turning in operation to straighten and flatten the stock form both sides.
- Now use VMC to drill out three holes of various diameters.
- Enlarge a centrally drilled hole to a diameter of 30 mm till 6 mm depth to make central hole to a counterbore hole.
- Use endmill to profile out the base elliptical part.
- At the end use EDM to cut out the required part form the stock.
- As part of finishing, use grinding wheel create smooth finish from all sides.

14.2 To Utilize the previously mentioned CNC operations to get final part made as shown in figure 21.

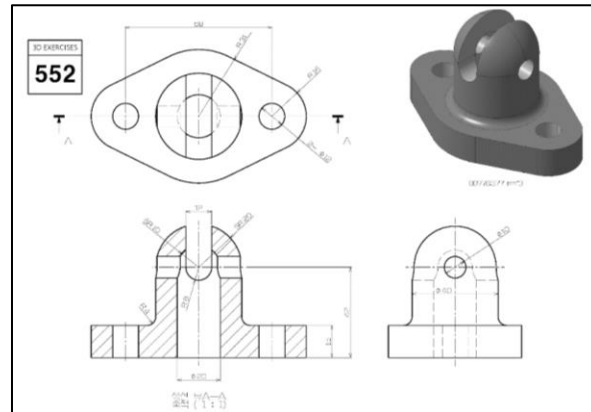


Figure 21: Final Component

Hints (Procedure to generate the code for part)

- Take a stock of 150 mm diameter x 70 mm for creating of part.
- Use CNC Lathe to perform facing and step turning in operation to straighten and flatten the stock form both sides.
- Now use VMC to drill out three holes of various diameters.
- Use endmill to create a slot on the cylindrical part.
- At the end use EDM to cut out the required part form the stock.
- As part of finishing, use grinding wheel create smooth finish from all sides.

Try

1. To use the canned cycles to optimize the cycle time for production of part.
2. To generate an automated code using MasterCAM for the part shown above.

V. TEXT BOOKS:

1. Peter Smid, CNC Control Setup for Milling and Turning: Mastering CNC Control Systems, Industrial Press Inc., 2010.
2. Stephen F. Krar, et al. Computer Numerical Control Simplified, Industrial Press Inc., 2001

VI. REFERENCE BOOKS:

1. C. Elanchezian, et al. Computer Aided Manufacturing, Firewall Media, 2007.
2. Chang, Tien-Chien, et al. Computer-aided manufacturing. United Kingdom, Pearson Prentice Hall, 2006.

VII. ELECTRONICS RESOURCES:

1. https://onlinecourses.swayam2.ac.in/nou22_me04/preview
2. https://onlinecourses.nptel.ac.in/noc22_me10/preview
3. <https://faculty.etsu.edu/hemphill/entc3710/nc-prog/index.htm>

VIII. MATERIALS ONLINE

1. Course template
2. Lab manual