

“A Study of CNC Milling Operations and Quality Inspection at Avadhoot Industries, Ahilyanagar.”

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Abstract

Industrial training is an important part of mechanical engineering education because it provides practical exposure to manufacturing processes, machine tools, quality-control systems and industrial safety. This paper presents a detailed study of CNC milling operations and quality inspection practices at Avadhoot Industries, Pune.

Avadhoot Industries, located in MIDC, Ahilyanagar, identifies itself as a manufacturer and supplier of CNC/VMC-machined components, turned components, CNC pipe-bent components, and plasma- and laser-cut components for automotive, non-automotive and medical-equipment applications. The company also states that it is an IATF 16949:2016 certified company and has more than 20 years of experience in precision metal components.

The study covers CNC milling-machine setup, workpiece clamping, tool selection, tool-offset setting, work-coordinate setting, machining operations, cutting parameters, component inspection and quality-control procedures. Government CNC training material identifies milling operations, workpiece holding, cutting tools, surface-finish inspection and final-product inspection as important competencies for CNC machining personnel.

The study demonstrates that accurate CNC machining depends on proper machine setup, appropriate cutting parameters, suitable tooling and systematic inspection. Quality inspection using precision measuring instruments is essential for ensuring that manufactured components conform to engineering drawings and specified tolerances.

Keywords: CNC Milling, VMC, CNC Machining, Quality Inspection, Metrology, Dimensional Accuracy, Industrial Training, Manufacturing, Quality Control.

1. Introduction

Manufacturing industries continuously require high productivity, dimensional accuracy, repeatability and consistent product quality. Conventional machining methods often require significant operator intervention, whereas Computer Numerical Control (CNC) machines allow machining operations to be controlled through programmed instructions.

CNC milling is particularly useful for manufacturing components containing:

- Slots
- Pockets
- Steps
- Holes
- Profiles
- Contours
- Chamfers
- Flat surfaces
- Complex geometries

Avadhoot Industries states that its manufacturing activities include CNC and VMC machining and turned components, along with CNC pipe bending, plasma cutting and laser cutting. The company serves automotive, non-automotive and medical-equipment manufacturing sectors.

Quality inspection is closely associated with CNC machining because even a small error in workpiece alignment, tool offset, cutting condition or tool wear can produce dimensional deviations.

Therefore, this industrial training study focuses on two major areas:

1. CNC milling operations
2. Quality inspection of machined components

2. Company Profile

2.1 Avadhoot Industries

Avadhoot Industries is located in MIDC, Ahilyanagar Maharashtra. According to the company's official website, it was formerly known as Milind Enterprises and has more than 20 years of experience in precision metal-component manufacturing.

Manufacturing capabilities

The company publicly lists:

- CNC machining
- VMC machining
- Turned components
- CNC pipe bending
- Plasma cutting
- Laser cutting

and states that its products serve:

- Automotive industries
- Non-automotive industries
- Medical-equipment manufacturers

The company states that its quality system is IATF 16949:2016 certified.

3. Objectives of Industrial Training

The main objectives of the training were:

1. To understand CNC milling technology.
2. To study the construction of a CNC/VMC machine.
3. To understand the CNC machining sequence.
4. To study workpiece setting and clamping.
5. To understand cutting-tool selection.
6. To study tool-offset setting.
7. To understand work-coordinate setting.
8. To study CNC milling operations.
9. To understand machining parameters.
10. To study dimensional inspection.
11. To understand precision measuring instruments.
12. To study quality-control practices.
13. To understand causes of machining defects.
14. To observe industrial safety practices.
15. To connect theoretical knowledge with actual manufacturing practice.

4. CNC Milling Machine

4.1 Definition

A CNC milling machine is a computer-controlled machine tool in which a rotating cutting tool removes material from a stationary or appropriately positioned workpiece.

A CNC/VMC can perform several operations using programmed tool movements.

The Directorate General of Training includes CNC/VMC operation, milling, cutting tools, workpiece holding, programming and quality inspection among the competencies of CNC machining technicians.

5. Main Parts of a CNC/VMC Machine

The major parts include:

5.1 Machine Bed

Supports the complete machine structure.

5.2 Column

Provides structural support to the spindle head and related mechanisms.

5.3 Spindle

Rotates the cutting tool at the required speed.

5.4 Work Table

Supports the work holding fixture and workpiece.

5.5 Tool Magazine

Stores multiple cutting tools.

5.6 Automatic Tool Changer

Automatically changes tools according to the CNC program.

5.7 Control Panel

Used to:

- Enter programs
- Edit programs
- Set offsets
- Start/stop machining
- Monitor machine status

5.8 Coolant System

Supplies coolant to the cutting zone for cooling and chip removal.

5.9 Guideways and Ball Screws

Provide controlled movement of machine axes.

6. CNC Machining Process

The general manufacturing sequence is:

Engineering Drawing

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Process Planning

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CAD/CAM Programming

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CNC Program Generation

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Raw Material Preparation

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Workpiece Clamping

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Tool Setting

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Work Coordinate Setting

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Trial Machining

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First-Piece Inspection



Batch Production



In-Process Inspection



Final Inspection



Packing & Dispatch

This sequence ensures that machining and inspection are integrated rather than treating quality inspection only as a final activity.

7. Workpiece Setting

Correct workpiece setting is one of the most important activities in CNC milling.

Procedure

1. Clean the work table.
2. Clean the fixture.
3. Place the workpiece correctly.
4. Clamp the component securely.
5. Check workpiece alignment.
6. Ensure adequate tool clearance.
7. Set work coordinate.
8. Verify component orientation.
9. Perform trial machining.

Incorrect clamping can result in:

- Dimensional errors
- Workpiece movement
- Chatter
- Tool damage
- Incorrect hole position
- Component rejection

8. Cutting Tools Used

Common CNC milling tools include:

Tool	Application
Face mill	Flat surface machining
End mill	Slot and profile machining
Ball-nose cutter	Curved/3D surfaces
Drill	Hole production
Reamer	Accurate hole finishing
Tap	Internal threading
Chamfer cutter	Edge chamfering
Counterbore tool	Counterbore production

Tool selection depends on:

- Workpiece material
- Required geometry
- Cutting depth
- Surface finish
- Dimensional accuracy
- Production quantity

9. CNC Milling Operations

9.1 Face Milling

Face milling produces a flat surface.

9.2 End Milling

End milling is used for slots, pockets and profiles.

9.3 Slot Milling

A cutter removes material to produce a slot of specified width and depth.

9.4 Pocket Milling

Pocket milling produces a cavity or recessed region.

9.5 Drilling

Drilling produces holes of specified diameter.

9.6 Reaming

Reaming improves hole dimensional accuracy and surface finish.

9.7 Tapping

Tapping produces internal threads.

9.8 Chamfering

Chamfering removes sharp edges.

9.9 Contour Milling

Contour milling produces curved or irregular profiles.

10. CNC Programming

CNC machines operate according to programmed instructions.

Important programming codes include:

G-Codes

Used mainly for geometrical and movement instructions.

Examples:

- G00 – Rapid positioning
- G01 – Linear interpolation
- G02 – Circular interpolation clockwise
- G03 – Circular interpolation counter-clockwise

M-Codes

Used for machine functions.

Examples:

- M03 – Spindle ON
- M05 – Spindle OFF
- M08 – Coolant ON
- M09 – Coolant OFF

Actual code usage varies according to the CNC controller and machine configuration.

11. Machining Parameters

Three important machining parameters are:

Cutting Speed

$$V = \frac{\pi DN}{1000}$$

Where:

- V = cutting speed, m/min
- D = cutter diameter, mm
- N = spindle speed, rpm

Therefore:

$$N = \frac{1000V}{\pi D}$$

Feed Rate

$$F = f_z Z N$$

Where:

- F = feed rate, mm/min
- f_z = feed per tooth
- Z = number of cutter teeth
- N = spindle speed

Depth of Cut

Depth of cut is the thickness of material removed in one machining pass.

Selection depends on:

- Workpiece material
- Tool material
- Machine power
- Tool diameter
- Required surface finish
- Required production rate

12. Quality Inspection

Quality inspection is a systematic process of determining whether a component satisfies specified requirements.

The CNC machining technician curriculum specifically includes identifying measuring instruments and inspecting the final product, as well as checking surface finish.

A typical inspection system is:

Raw Material Inspection

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First-Piece Inspection

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In-Process Inspection

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Final Inspection

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Dispatch

13. First-Piece Inspection

The first component manufactured after machine setup is inspected carefully.

Important dimensions are compared with the engineering drawing.

If the component is within the specified tolerance, batch production can proceed according to the applicable production-control procedure.

First-piece inspection helps prevent the

production of a large number of defective components.

14. In-Process Inspection

In-process inspection is performed during production.

The operator or quality inspector may check:

- Length
- Width
- Thickness
- Hole diameter
- Hole location
- Slot dimensions
- Pocket depth
- Surface finish
- Chamfer
- Profile

The frequency of inspection should follow the company's inspection plan or control plan.

15. Final Inspection

Final inspection verifies that completed components meet the specified requirements before acceptance and dispatch.

It may include:

- Dimensional inspection
- Visual inspection
- Surface-finish inspection
- Thread inspection
- Geometrical inspection
- Functional inspection

16. Measuring Instruments

16.1 Vernier Caliper

Used for general dimensional measurement.

16.2 Micrometer

Used for high-accuracy external measurements.

16.3 Vernier Height Gauge

Used for height measurement and marking.

16.4 Dial Test Indicator

Used for:

- Runout
- Alignment
- Flatness
- Position checking

16.5 Bore Gauge

Used for measuring internal diameters.

16.6 Thread Gauge

Used to check internal or external threads.

16.7 CMM

A Coordinate Measuring Machine can be used for measuring complex geometrical features with high

accuracy.

Government training resources identify instruments such as vernier calipers, micrometers, height gauges and dial indicators as important metrology equipment.

17. Quality Parameters

The major quality parameters in CNC milling include:

Dimensional Accuracy

The measured dimension must fall within the specified tolerance.

Surface Finish

Surface roughness affects component performance and appearance.

Flatness

Ensures the surface does not have excessive deviation from the required plane.

Perpendicular

Ensures that two surfaces or features maintain the specified angular relationship.

Parallelism

Ensures that two surfaces remain parallel within the specified tolerance.

Position Accuracy

Ensures holes and other features are located correctly.

18. Sources of Machining Errors

Common causes include:

Machine-related

- Machine vibration
- Spindle runout
- Guideway problems
- Poor machine alignment

Tool-related

- Tool wear
- Incorrect tool selection
- Tool breakage
- Improper tool offset

Material-related

- Material variation
- Improper hardness
- Internal stresses

Operator-related

- Incorrect workpiece setting
- Incorrect offset
- Incorrect program selection
- Improper inspection

Process-related

- Incorrect cutting speed
- Excessive feed
- Excessive depth of cut
- Poor coolant application

19. CNC Milling Defects and Corrective Actions

Defect	Possible Cause	Corrective Action
Poor surface finish	Tool wear/vibration	Check tool and machining conditions
Oversize dimension	Incorrect offset	Correct tool offset
Undersize dimension	Tool wear/incorrect offset	Inspect tool and compensate
Burr formation	Improper cutting condition	Optimize tool/cutting condition
Chatter	Poor rigidity	Improve clamping/tool overhang
Incorrect hole location	Work-coordinate error	Verify work offset
Tool breakage	Excessive cutting load	Review cutting parameters
Taper	Alignment/tool deflection	Check setup and machine condition

20. Quality-Control Methodology

A systematic quality-control methodology can be represented as:

Customer Drawing

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Identify Critical Characteristics

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Process Planning

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Machine Setup

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First-Piece Inspection

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Process Approval

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Production

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Periodic Inspection

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Final Inspection

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Non-Conforming Product Control

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Corrective Action

This approach is consistent with the broader objectives of industrial CNC training, where product specifications, machining processes, measurement and final inspection are treated as connected competencies.

21. Industrial Training Activities

The training can be documented in the following sequence.

Day Training Activity
Day 1 Company introduction and safety
Day 2 CNC/VMC machine identification
Day 3 Engineering drawing study
Day 4 Workpiece setting
Day 5 Cutting-tool identification
Day 6 Tool-offset setting
Day 7 Work-coordinate setting
Day 8 CNC program observation
Day 9 Face milling
Day 10 Slot milling
Day 11 Pocket milling
Day 12 Drilling
Day 13 Tapping
Day 14 Component inspection
Day 15 Measuring instruments
Day 16 In-process inspection
Day 17 Final inspection
Day 18 Defect analysis
Day 19 Quality-control documentation
Day 20 Overall training review
You can change these activities according to the actual training days attended by Nikhil.

22. Safety Practices

Safety is an essential part of CNC machining. The trainee/operator should:

- Wear safety shoes.
- Use safety glasses where required.
- Avoid loose clothing.
- Never touch rotating tools.
- Never remove chips by hand.
- Use appropriate chip-removal tools.
- Keep the machine enclosure closed during operation.
- Stop the machine before inspection where required.
- Follow machine-specific emergency-stop procedures.
- Follow authorized maintenance/lockout procedures.
- Maintain good housekeeping.

DGT training material specifically includes safe working practices, environmental regulations and housekeeping as CNC-machining learning outcomes.

23. Observation During Training

The important observations from the industrial training can be summarized as follows:

1. CNC machining provides high repeatability.
2. Proper workpiece clamping is essential.
3. Tool selection affects productivity and surface quality.
4. Tool wear can gradually affect component dimensions.
5. Correct tool offsets are necessary for dimensional accuracy.
6. First-piece inspection reduces the possibility of batch rejection.
7. Measuring instruments must be appropriate for the required tolerance.
8. In-process inspection helps detect process variation.
9. Proper machine operation requires trained personnel.
10. Safety and housekeeping are integral parts of CNC manufacturing.

24. Sample Inspection Table

The following table can be included in the report. Replace the sample values with Nikhil's actual inspection readings.

Sr. No.	Parameter	Drawing Requirement	Measured Value	Status
1	Overall length	As drawing	per ____ mm	OK/NG
2	Width	As drawing	per ____ mm	OK/NG
3	Thickness	As drawing	per ____ mm	OK/NG
4	Hole diameter	As drawing	per ____ mm	OK/NG
5	Hole position	As drawing	per ____ mm	OK/NG
6	Pocket depth	As drawing	per ____ mm	OK/NG
7	Slot width	As drawing	per ____ mm	OK/NG
8	Surface finish	As drawing	per ____	OK/NG

25. Advantages of CNC Milling

CNC milling provides:

- High accuracy
- Repeatability
- Improved productivity
- Reduced manual intervention
- Complex-profile machining
- Better process consistency
- Reduced operator-dependent variation

- Suitable for batch production
- Better utilization of cutting tools when parameters are optimized

26. Limitations

Some limitations include:

- High initial investment
- Requirement of trained operators
- Programming expertise
- Tool wear
- Machine maintenance requirements
- Dependence on correct setup
- Cost of precision inspection equipment

27. Results and Discussion

The industrial training demonstrates that CNC milling and quality inspection are closely connected.

A CNC machine may produce a component repeatedly, but repeatability alone does not guarantee that the component satisfies the engineering drawing. Correct tool offsets, workpiece alignment, cutting conditions and tool condition must be maintained.

Quality inspection provides feedback about the machining process. For example, if a dimension gradually moves toward the upper or lower tolerance limit, this may indicate tool wear or process variation. The operator can then investigate the tool condition and make an appropriate authorized correction.

The training also demonstrates the importance of metrology. A measuring instrument must have sufficient accuracy and be suitable for the dimension being checked. Government skill-development programs separately identify metrology, engineering inspection, CNC and production technology as important industrial skill areas.

28. Suggestions for Improvement

The following improvements can be considered:

1. Tool-Life Monitoring

Record tool usage and replace tools based on established tool-life criteria.

2. SPC

Statistical Process Control can be used to monitor critical dimensions.

3. Digital Inspection Records

Record inspection results digitally to identify trends.

4. Preventive Maintenance

Follow machine-specific preventive-maintenance schedules.

5. Operator Training

Provide regular training on CNC programming, tooling, metrology and safety.

6. OEE Monitoring

Monitor:

- Availability
- Performance
- Quality

to evaluate machine effectiveness.

7. First-Piece Approval

Use a documented first-piece inspection procedure before batch production.

29. Future Scope

Future development opportunities include:

- Industry 4.0-based machine monitoring
- IoT-enabled CNC machines
- Automatic tool-wear detection
- In-process probing
- Automated CMM inspection
- Artificial-intelligence-based defect detection
- Predictive maintenance
- Digital production records
- Automated process-data collection
- Real-time OEE monitoring

30. Conclusion

The industrial training at Avadhoot Industries, Pune provided practical exposure to CNC/VMC machining and quality inspection. The company publicly identifies CNC/VMC machining as one of its core manufacturing capabilities and serves automotive, non-automotive and medical-equipment sectors.

The study covered the complete basic CNC milling workflow, including drawing interpretation, workpiece setting, tool selection, tool-offset setting, work-coordinate setting, machining operations and component inspection.

The training also demonstrated that quality cannot be separated from the machining process. Proper machine setup, suitable cutting tools, correct machining parameters, regular inspection and competent operators are required to achieve consistent results.

Overall, the training helped develop practical knowledge of CNC machining, production technology, metrology, quality control and industrial safety, providing a useful connection between mechanical-engineering theory and industrial manufacturing practice.

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