

NAAN MUDHALVAN – POLYTECHNIC – ODD SEMESTER 2025-26

COURSE CURRICULUM

CNC MILLING

ABOUT THE COURSE

This industry-aligned course equips students with the skills to operate CNC milling machines for precision manufacturing. It covers multi-axis operations, machining complex components, interpreting ISO engineering drawings with GD&T, and developing CAM programs with G-code. The students gain hands-on experience in setup, toolpath optimization, surface finishing, inspection, and batch production for aerospace, automotive, and medical applications. The course includes project-based modules, supported by industry-standard tools like MasterCAM, FreeCAD, and FANUC controllers.

COURSE NAME:	CNC Milling
TOTAL DURATION:	60 HRS
MODE OF DELIVERY	PHYSICAL CLASSROOM TRAINING AT RESPECTIVE COLLEGES
TRAINER TO STUDENT RATIO:	1:60
TOTAL MARKS:	70 (External) + 30 (Internal)

TABLE 1

OVERALL COURSE OBJECTIVE	• Develop advanced CNC milling skills, including multi-axis operations, CAM programming, precision measurement, and quality assurance, aligned with WorldSkills standards for high-precision industrial applications.
LEARNING OUTCOME	• Perform multi-axis milling operations on complex parts using CNC milling machines with precision and accuracy. • Execute pocketing, contouring, drilling, tapping, and thread milling on aluminium, steel, and titanium. • Interpret ISO drawings and GD&T symbols for defining tolerances. • Develop and optimize CNC programs using CAM and G-code. • Set up machines with correct tool offsets and fixtures following safety protocols. • Measure and verify parts using micrometres, vernier callipers, and CMM. • Apply finishing techniques for surface quality per industry standards.

	• Perform routine maintenance and troubleshooting. • Manage batch production ensuring consistency and optimization. • Machine mating components and assemblies with precise fits and tolerances.
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TABLE 2: MODULE-WISE COURSE CONTENT AND OUTCOME				
SL.NO	MODULE NAME	MODULE CONTENT	MODULE LEARNING OUTCOME	DURATION (HRS)
1	Multi-Axis CNC Milling	Introduction to multi-axis operations, toolpaths, and strategies for machining complex geometries	Perform multi-axis milling on complex parts using CNC milling machines with precision and accuracy	8
2	Pocketing, Drilling & Thread Milling	Pocketing, contouring, drilling, tapping, and thread milling techniques on various materials	Execute pocketing, contouring, drilling, tapping, and thread milling on aluminum, steel, and titanium	8
3	Engineering Drawing & GD&T	Reading and interpreting ISO engineering drawings, dimensions, tolerances, and GD&T symbols	Interpret and apply ISO engineering drawings and GD&T symbols to define machining parameters and tolerances	7
4	CAM Programming & G-code	CAM toolpath generation, simulation, and G-code optimization for multi-step machining	Develop and optimize CNC milling programs using CAM software and G-code for 3D and multi-face machining	8
5	CNC Machine Setup & Safety	Tool offset measurement, workpiece clamping, PPE compliance, and emergency handling	Set up CNC milling machines with correct tool offsets, fixtures, and follow safety protocols	5

6	Measurement & Inspection	Dimensional verification using micrometres, vernier callipers, and CMM; surface roughness measurement	Measure and verify tolerances and surface finish of machined parts using precision instruments	5
7	Surface Finishing Techniques	Polishing, deburring, chamfering; achieving required Ra values and surface quality	Apply finishing techniques to meet industry-specific surface finish and quality standards	4
8	Maintenance & Troubleshooting	Tool inspection, machine cleaning, fault detection, and basic troubleshooting	Perform routine maintenance, tool inspection, cleaning, and basic fault correction	4
9	Batch Production Process	Efficient tool and fixture changes, cycle time optimization, documentation of production parameters	Manage batch production ensuring repeatability, tool change efficiency, and process optimization	6
10	Machining for Assembly Fit	Techniques for machining parts that fit together accurately; application of functional GD&T	Machine mating components and assemblies with precise fits and functional geometric tolerances	5

TABLE 3: OVERALL COURSE LEARNING OUTCOME ASSESSMENT CRITERIA AND USECASES				
LEARNING OUTCOME	ASSESSMENT CRITERIA	PERFORMANCE CRITERIA	USECASES	
Perform multi-axis milling operations on complex parts using CNC milling machines with precision and accuracy.	- Machined parts meet specified dimensional tolerances (IT6–IT7). - Correct selection and use of milling tools and parameters. - Smooth surface finishes achieved as per project requirements.	- Machine a multi-feature aluminium fixture block. - Mill a steel assembly bracket with mating features. - Produce a robotic arm base with circular bosses and stepped pockets.	Perform multi-axis milling operations on complex parts using CNC milling machines with precision and accuracy.	

	- Safe and proper machine operation demonstrated.		
Execute pocketing, contouring, drilling, tapping, and thread milling on various materials including aluminium, steel, and titanium.	- Pockets and contours machined to correct dimensions and tolerances. - Thread profiles (metric, BSP) accurately milled. - Drilled and tapped holes meet size and positional tolerances. - Surface finish in machined features meets specified Ra values ($\leq 1.6 \mu\text{m}$).	- Create a flanged gear housing prototype with 3D pockets and threads. - Mill a tooling plate with a grid of holes and engraved logos. - Manufacture a mini mould core with coolant channels.	Execute pocketing, contouring, drilling, tapping, and thread milling on various materials including aluminium, steel, and titanium.
Interpret and apply ISO engineering drawings and GD&T symbols to define machining parameters and dimensional tolerances.	- Accurate identification of key dimensions, tolerances, and GD&T symbols. - Correct translation of drawing requirements into machining plans. - Ability to identify flatness, concentricity, and position tolerance.	- Analyse aerospace component drawings. - Apply GD&T in machining plans. - Practice reading tolerance drawings for flatness and concentricity.	Interpret and apply ISO engineering drawings and GD&T symbols to define machining parameters and dimensional tolerances.
Develop and optimize CNC milling programs using CAM software and G-code for multi-step machining, including 3D surface milling and multi-face setups.	- Programs generated with correct toolpaths and cutting parameters. - G-code files are error-free and simulate tool movement. - Efficient tool changes and	- Program a heat sink base with thin fins. - Generate toolpaths for a wheel hub profile. - Optimize G-code for a control panel with engraved labels.	Develop and optimize CNC milling programs using CAM software and G-code for multi-step machining, including 3D surface milling and multi-face setups.

	cycle time optimization. - Correct use of coordinate systems and fixtures.		
Set up CNC milling machines with correct tool offsets, work holding fixtures, and adhere to safety protocols for effective machining.	- Accurate measurement and input of tool offsets. - Secure and accurate work holding and fixture setup. - Compliance with PPE and safety procedures. - Proper machine start up, shutdown, and emergency response.	- Machine setup for bracket production. - Tool offset calibration and alignment. - Safety checks and emergency stop practice.	Set up CNC milling machines with correct tool offsets, work holding fixtures, and adhere to safety protocols for effective machining.
Measure and verify dimensional tolerances and surface finishes of machined parts using precision instruments such as micrometres, vernier callipers, and CMM.	- Proper use of micrometres, verniers, and CMM. - Measurements within specified tolerances. - Surface roughness verification. - Complete documentation of inspection data.	- Inspect pockets, holes, and profiles on parts. - Measure surface finish on aerospace parts. - Document inspection results for QC.	Measure and verify dimensional tolerances and surface finishes of machined parts using precision instruments such as micrometres, vernier callipers, and CMM.
Apply finishing techniques to achieve specified surface roughness and meet quality standards required in aerospace, automotive, and medical industries.	- Surface finish meets specified Ra range (e.g., 0.8–3.2 μm). - Proper use of finishing tools and techniques. - Consistency of finish across multiple parts. - Absence of burrs and tool marks.	- Polish medical device components. - Deburr automotive parts. - Ensure consistent finish for batch enclosures.	Apply finishing techniques to achieve specified surface roughness and meet quality standards required in aerospace, automotive, and medical industries.

Perform routine maintenance, tool inspection, machine cleaning, and troubleshooting to ensure continuous machine performance and safety.	- Regular inspection and replacement of tools. - Machine and workspace cleaning. - Identification and reporting of faults. - Basic corrective actions or escalation.	- Inspect tools after milling runs. - Clean CNC machine and area post-shift. - Troubleshoot chatter and alignment issues.	Perform routine maintenance, tool inspection, machine cleaning, and troubleshooting to ensure continuous machine performance and safety.
Manage batch production processes ensuring repeatability, efficient tool changes, and process optimization for small to medium scale manufacturing.	- Batches produced with minimal dimensional variance. - Efficient tool and fixture changeover times. - Maintain consistent quality in batches. - Accurate documentation of production parameters.	- Batch machining of heat sink base plates. - Tool/fixture changes between jobs. - Optimise cycle time and toolpaths.	Manage batch production processes ensuring repeatability, efficient tool changes, and process optimization for small to medium scale manufacturing.
Demonstrate the ability to machine mating components and assemblies with precise fits and functional geometric tolerances.	- Machined parts meet assembly fits (clearance/interference). - Threaded holes and parts align properly. - Assembly without excessive force or gaps. - Meets required finish and dimensional accuracy.	- Assemble dual-part locator jig with ± 0.02 mm fit. - Produce enclosures with tight dimensional control. - Test bolt hole alignments in flanged assemblies.	Demonstrate the ability to machine mating components and assemblies with precise fits and functional geometric tolerances.

TABLE 4: LIST OF FINAL PROJECTS (20 PROJECTS THAT COMPREHENSIVELY COVER ALL THE LEARNING OUTCOME)	
SL. NO.	FINAL PROJECT (The Training Partner shall cover all the steps to complete a given project)
1	Multi-Feature Aluminium Fixture Block with Pockets and Threads
2	Steel Assembly Bracket with Mating Features and Tolerances
3	Flanged Gear Housing Prototype with 3D Surface Machining
4	CNC-Machined Tooling Plate with Threaded Hole Grid
5	Mini Mould Core with Complex Pockets and Coolant Channels
6	Heat Sink Base Plate with Thin Parallel Fins and Mounting Holes
7	Robotic Arm Base with Circular Bosses and Stepped Pockets
8	Custom Wheel Hub with Profile Contouring and Bolt Pattern
9	CNC Control Panel Faceplate with Slots and Engraved Labels
10	Dual-Part Locator Jig with Precision Fit and Dowel Pin Holes
11	Aerospace Bracket with Multi-Surface Machining and Tolerances
12	Titanium Medical Implant Component with Mirror Finish
13	Injection Mould Insert with Island and Step Pockets
14	Electronic Enclosure Housing with Complex Contours
15	Automotive Engine Mount with Bosses and Threaded Holes
16	Precision Gear Blank with Multi-Face Machining
17	Cooling Manifold Base with Multiple Port Machining
18	Custom Industrial Sensor Housing with Tight Dimensional Control
19	Aerospace Turbine Blade Fixture with Complex Pocketing
20	Multi-Face Fixture Plate with Engraving and Reamed Holes

TABLE 5: COURSE ASSESSMENT RUBRICS (TOTAL MARKS: 70)				
ASSESSMENT CRITERIA	DESCRIBE THE CRITERIA OF THE BELOW CATEGORY PERFORMANCE			TOTAL MARKS
	FAIR (Below Expectations)	GOOD (Meets Expectations)	EXCELLENT (Exceeds Expectations)	
Drawing Interpretation	Misreads or omits critical dimensions, tolerances, or GD&T symbols; inaccurate setup.	Correctly interprets most dimensions and GD&T; minor errors in application.	Accurately interprets all drawing elements and applies tolerances with precision.	10
CAM Program Development	Contains errors, inefficient toolpaths, or incorrect parameters; leads to defects.	Program runs with few errors; acceptable toolpaths and cutting conditions.	Optimized, error-free CAM programs and G-code with efficient toolpaths and minimal cycle time.	20

Machine Setup & Safety	Inaccurate tool offset or fixture setup; neglects safety checks or PPE compliance.	Proper offsets and fixture clamping; basic safety protocols followed.	Precise setup, full PPE usage, proactive safety checks, and emergency preparedness demonstrated.	10
Machining Accuracy	Machined features incomplete or outside tolerance range.	All features completed within acceptable tolerances.	High-precision machining with tight tolerances, excellent repeatability, and clean features.	10
Measurement & Inspection	Incorrect or missing measurements; poor documentation.	Measurements are mostly accurate with basic documentation.	Expert-level use of instruments, thorough verification, and clear, well-organized records.	10
Surface Finish Quality	Surface is rough, inconsistent, or outside required Ra limits.	Surface finish meets basic specs with some inconsistencies.	Smooth, uniform surface finish exceeding project specifications with no tool marks or burrs.	10
Total				70

Technical Specification

S. No.	Details	Specifications
1	Software/Tools used	SOLIDWORKS MasterCAM - v2023 FreeCAD- Latest CAMotics - Latest NCViewer - Web based LinuxCNC - Stable Fanuc Manual Guide I
2	Kit(s) used	CNC Milling Machine 3 axis VMC with FANUC Controller, Auto Tool Changer, Coolant System FANUC Simulator Fanuc Manual Guide i, keypad & interface unit CAM Workstation High performance PC with CAM tools and simulator software

		Measurement Kit Micrometer, Vernier, Surface Roughness Comparator, CMM access Tooling Kit End mills, slot drills, threading cutters, chamfer tools, tool holders Workholding Kit Vices, clamps, step blocks, parallels Finishing Tool Kit Deburring tools, polishing wheels, surface measuring
3	Total Kits available	• CNC Milling Machines - 10 Units • FANUC Simulators - 12 Units • CAM Workstations - 20 Units • Measurement Kits - 30 Sets • Tooling Kits - 18 Sets • Workholding Kits - 18 Sets • Finishing Tool Kits - 12 Sets
4	No. of kits per batch	• CNC Milling Machines - 2 Units • FANUC Simulators - 3 Units • CAM Workstations - 6 Units • Measurement Kits - 10 Sets • Tooling Kits - 6 Sets • Workholding Kits - 6 Sets • Finishing Tool Kits - 4 Sets
5	Major Demonstration Kits	Multi Feature Machining Demonstration Setup CNC milling machine + surface finish analysis station Demonstrates: Complex toolpaths, Ra validation, 3D contouring, and assembly fitting Units used: 1–2 units per session
6	Certification	Joint certificate by TNSDC and Penta CAD Technology