

## GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

### Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)

IV – Semester

Course Title: **CNC Machines and 3D Printing**

(Course Code: 4344105)

Diploma programmer in which this course is offered	Semester in which offered
Automation and Robotics	Fourth

#### 1. RATIONALE

The CNC Machines & Additive Manufacturing curriculum is designed to address the pressing demands of modern manufacturing industries. With CNC machines and Additive Manufacturing (AM) technologies at the forefront of industrial innovation, this subject equips students with essential skills for precision engineering and rapid prototyping. The curriculum ensures relevance by incorporating the latest technological advancements, fostering hands-on experience in programming and operating CNC machines, and exploring the diverse applications of AM in various industries. Interdisciplinary in nature, the subject integrates principles from mechanical engineering, computer science, and materials science, cultivating a holistic understanding of advanced manufacturing processes. Recognizing the global competitiveness of professionals in this field, the curriculum emphasizes adaptability and encourages a mindset of lifelong learning. Moreover, it addresses sustainability concerns by exploring the eco-friendly aspects of AM. Ultimately, the CNC Machines & Additive Manufacturing curriculum aims to produce graduates who are not only technically proficient but also innovative, adaptable, and well-prepared to contribute meaningfully to the evolving landscape of modern manufacturing.

#### 2. COMPETENCY

The course content should be taught and implemented with the aim to develop different types of skills so that students are able to acquire following competency.

- **Students will demonstrate proficiency in operating CNC machines, programming, and utilizing Additive Manufacturing technologies, fostering interdisciplinary skills essential for advanced manufacturing in various industries.**

#### 3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

CO-1	To demonstrate the working of a CNC machine
CO-2	Develop the part program and simulation of the part program in a CNC Machine.
CO-3	To demonstrate interface software between CAD and CAM for auto part programming.
CO-4	Expose the students to different types of Rapid prototyping processes, materials used in RP systems.

#### 4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	30*	70	25*	25	150

(\*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

**Legends:** L-Lecture; T- Tutorial/Teacher Guided Theory Practice; P -Practical; C – Credit, CA - Continuous Assessment; ESE -End Semester Examination.

## 5. SUGGESTED PRACTICAL EXERCISES

Following practical outcomes (PrOs) are the sub-components of the Course Outcomes (Cos). Some of the PrOs marked ‘\*’ are compulsory, as they are crucial for that particular CO at the ‘Precision Level’ of Dave’s Taxonomy related to ‘Psychomotor Domain’.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	<p><b>Demonstrate constructional features of CNC:</b></p> <ol style="list-style-type: none"> <li>Demonstrate the CNC machines and their operations.</li> <li>Identify the major parts of CNC and draw a sketch.</li> <li>Write the specifications of CNC taken for demonstration.</li> <li>Importance of tool holders, and types of CNC tools.</li> <li>Tabulate sensors/feedback devices with type, specification, and purposes used on CNC taken for demonstration.</li> </ol>		
2	<p><b>CNC turning part programming:</b></p> <p>The teacher will assign part drawings. A minimum of five drawings having the following details are to be assigned. This includes parts- (i) Simple turning with steps, (ii) Turning with tapers, (iii) Turning with circular (concave/convex shape) interpolation, (iv) Turning using canned cycle - with threading or drilling or other and (v)Turning with use of canned cycle and subroutine. Students should do the following activities:</p> <ol style="list-style-type: none"> <li>Sketch of each part with dimensions.</li> <li>Prepare the CNC part program using G and M codes with ISO format.</li> <li>Show various zeros and tool paths on the part sketch with color codes and dimensions.</li> <li>Simulate the prepared part programs using available simulation software.</li> <li>Prepare the parts on CNC Machines.</li> </ol>		
3	<p><b>CNC machining center part programming:</b></p> <p>The teacher will assign part drawings. A minimum of five drawings having the following details are to be assigned. This includes parts- (i) Simple turning with steps, (ii) Turning with tapers, (iii) Turning with circular (concave/convex shape) interpolation, (iv) Turning using canned cycle - with threading or drilling or other and (v)Turning with use of canned cycle and subroutine. Students should do the following activities:</p> <ol style="list-style-type: none"> <li>Sketch of each part with dimensions.</li> <li>Prepare the CNC part program using G and M codes with ISO format.</li> <li>Show various zeros and tool paths on the part sketch with color codes and dimensions.</li> <li>Simulate the prepared part programs using available simulation software.</li> <li>Prepare the parts on CNC Machines.</li> </ol>		
4	<p><b>Demonstrate the automated CNC program in Mater CAM /Inventor-CAM/Solid Works</b></p> <ol style="list-style-type: none"> <li>Selection of reference axis selection of models for automated CNC programs for the relevant type of CNC machines.</li> </ol>		

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	<b>b.</b> Simulation of automated CNC program with tool and tool holder selection, Tool compensation methods tool offset. <b>c.</b> Demonstrate CAD / CAM integration in the above-mentioned CAM Software. <b>d.</b> Demonstrate on CNC Lathe, or VMC for work holding, Tool compensation methods, and tool offset. <b>e.</b> (Optional) Run the automated CNC program prepared from above mentioned CAD-CAM software in the CNC machine or CNC trainer.		
5	<b>Rapid prototyping machine(3D printer) (Demonstration )</b> To study the part builds mechanism of a Rapid prototyping machine. <b>a.</b> To develop CAD models using 3D Scanner/Software for 3D printer. <b>b.</b> To select a specific material for the given application. <b>c.</b> To produce a simple product using 3D printing or Additive Manufacturing (AM)		
6	<b>Industrial Visit:</b> Visit nearby industries having CNC machines. List and state important features of them with detailed specifications and names of manufacturers and safety criteria.	All	00
7	<b>Mini Project and Presentation:</b> <b>a.</b> Teacher will assign any one topic to each batch student. Each student will have different topic. <b>b.</b> Using power point presentation, each student will present the topic. Presentation must include related Videos/images. <b>c.</b> Present the topic and submit the report of same.	All	02
		Total	<b>28</b>

### **Note**

- i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*
- ii. Care must be taken in assigning and assessing study report as it is a Second-year study report. Study report, data collection and analysis report must be assigned in a group. Teacher has to discuss about type of data (which and why) before group start their market survey.*

The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.

Sr. No	Sample Performance Indicators for the PrOs	Weightage in %
1	Knowledge	20
2	Quality of Report/Sketch/Drawings/Jobs.	30
3	Participation	30
4	Punctuality	20
	Total	<b>100</b>

## 6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

These major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to user in uniformity of practical in all institutions across the state.

Sr. No	Equipment Name with Broad Specifications	PrO. No.
1.	CNC Lathe machine or CNC trainer and different types of CNC tools.	
2.	VMC Machine or VMC trainer and different types of CNC tools.	
3.	Vernier, Micrometer, Surface plate.	
4.	Cad Workstation with Software: Suggested Workstation configuration: <ul style="list-style-type: none"> <li>• Intel i3 (10th generation and above)/Intel i5(8<sup>th</sup> generation and above)/intel i7 (6th generation)/Ryzen5 (5th generation and above)/Ryzen 7 (4th generation and above).</li> <li>• 8GB or above DDR3/DDR4/DDR5 RAM</li> <li>• 500 GB SSD or NVME M.2 SSD</li> <li>• Internet.</li> <li>• Integrated or external UHD graphic card</li> </ul> Software for CAD-CAM (Any One): <ul style="list-style-type: none"> <li>• AutoCAD (Free educational version for educator/student is available*)</li> <li>• Autodesk Inventor Professional with CAM feature (Free educational version for educator/student is available*).</li> <li>• Unigraphics with CAM feature.</li> <li>• SolidWorks with CAM feature.</li> <li>• Mastercam.</li> </ul>	
5.	Rapid Prototyping Machine	

\*Account in Autodesk website, documents, authority letter, transcript, I-card required

## 7. AFFECTIVE DOMAIN OUTCOMES

The following **sample** Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfill the development of this course competency.

- a) Work as a leader/a team member.
- b) Follow safety practices.
- c) Follow ethical practices
- d) Maintain tools and equipment
- e) Practice environment friendly methods and processes. (Environment related)

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- i. 'Valuing Level' in 1<sup>st</sup> year
- ii. 'Organization Level' in 2<sup>nd</sup> year.
- iii. 'Characterization Level' in 3<sup>rd</sup> year.

## 8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
<b>Unit – I</b>  <b>Introduction of CNC and CNC Machine Tools.</b>	1a. Introduction of NC, CNC, and DNC. 1b. Introduction of CNC Machine tools.	1.1 CAM Concepts & definitions. 1.2 NC, CNC, & DNC concept, Feature & difference. 1.3 Advantages & Limitations & Application of CNC. 1.4 Selection Criteria of CNC Machines. 1.5 Types of CNC Tools and Tool Holders. 1.6 CNC machines: Types, classification, working and constructional features.
<b>Unit – II</b>  <b>CNC machine components.</b>	2a. Identify the role of the main components of CNC machines. 2b. Identify CNC axes. 2c. Identify different zeros in CNC Machines	2.1 CNC Machine building, structural details, CNC block diagram. 2.2 Spindle drives and axes drives on CNC machines. 2.3 Components of CNC machines Types, sketch, working and importance of: <ol style="list-style-type: none"> <li>i. Different types of drives</li> <li>ii. Slideways.</li> <li>iii. Re-circulating ball screw.</li> <li>iv. Feedback devices (transducers, encoders).</li> <li>v. Automatic tool changer(ATC).</li> <li>vi. Automatic pallet changer (APC).</li> </ol>
<b>Unit – III</b>  <b>CNC part programming and recent trends.</b>	3a. Interpret the ISO format of CNC part programming with used codes. 3b. Prepare part program by using applicable codes like G & M etc. 3c. Apply advanced CNC part programming features like a canned cycle, subroutine, etc. 3d. Describe the procedure for Setting various compensations on CNC. 3e. Recent trends in CNC Part programming.	3.1 Definition and importance of various positions like machine zero, home position, workpiece zero, and program zero. 3.2 CNC part programming: programming format and structure of the part program 3.3 ISO G and M codes for turning and milling-meaning and applications of important codes. 3.4 Simple part programming for turning using ISO format having straight turning, taper turning (linear interpolation), and convex/concave turning (circular interpolation). 3.5 Simple part programming for milling using ISO format. 3.6 Importance, types, applications, and format for: <ul style="list-style-type: none"> <li>• Canned cycles.</li> <li>• Subroutine</li> </ul>

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
		3.7 CNC turning and milling part programming using canned cycles and Subroutine. 3.8 Need and importance of various compensations: <ul style="list-style-type: none"> <li>• Tool length compensation.</li> <li>• Pitch error compensation.</li> <li>• Tool radius compensation.</li> <li>• Tool offset.</li> </ul> 3.9 Introduction of CAM software and application of automated part programming method & its feature scope.
<b>Unit-VI</b>  <b>Introduction to Rapid Prototyping</b>	4a. Explain Introduction, classification, application of rapid prototyping.	4.1 Fundamentals of Rapid Prototyping, advantages and limitations. 4.2 Classification of Rapid prototyping methods 4.3 Applications of rapid prototyping methods  4.1 Working principle, process detail of <ul style="list-style-type: none"> <li>• Liquid State-based AM Processes</li> <li>• Solid State-based AM Processes</li> <li>• Powder Based AM Processes</li> </ul>
<b>Unit-V</b>  <b>Rapid Prototyping Techniques.</b>	5a. Rapid prototyping methods, working principle, detail of process	5.1 Liquid State-based AM Processes Stereo lithography-Process and working principle; Photopolymers; Photo polymerization, layering technology, Laser and Laser scanning; Micro-stereolithography;  5.2 Solid State-based AM Processes Fused Deposition Modeling – Process, working principle and materials; Equipment and specifications. Laminated object manufacturing – Process and working principle; Equipment and specifications.  5.3 Powder Based AM Processes Powder Bed Fusion Processes – Working principle and materials; Powder fusion mechanism and powder handling Selective laser Sintering, Electron Beam Melting, Laser Engineered Net Shaping, Binder Jetting and Direct Metal Deposition; Comparison between LBF processes

## 9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
1	Introduction of CNC and CNC Machine Tools.	4	3	3	-	6
2	CNC machine components.	6	4	4	-	8
3	CNC part programming and recent trends.	16	7	7	14	28
4	Introduction to Rapid Prototyping	6	4	4	-	8
5	Rapid Prototyping Techniques.	10	3	7	4	20
Total		42	17	23	30	70

**Legends:** R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)

## 10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related **co-curricular** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should perform following activities in group and prepare reports of about 5 pages for each activity. They should also collect/record physical evidences for their (student's) portfolio which may be useful for their placement interviews:

- Select two industrial components (approved by teacher) and list various machine tools and operations used to produce these components.
- Prepare a list of surrounded items which are prepared by machining processes.
- Collect/download at least four different machine tool catalogues and make report of that with price.
- List various machine tools (min. 5 machine) currently using in market for different operation to perform.
- Identify the process use for re-sharpening different types of tools and prepare report for minimum 3 tools

## 11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

- Massive open online courses (**MOOCs**) may be used to teach various topics/sub topics.
- To acquire knowledge of basic machine, tool and their operation arrange two or more **industrial visit** of production industry. After visit student must be submit their industrial visit report.
- Guide student(s) in undertaking micro-projects.
- 'L' in section No. 4 means different types of teaching methods that are to be employed by teachers to develop the outcomes.
- About **20% of the topics/sub-topics** which are relatively simpler or descriptive in nature is to be given to the students for **self-learning**, but to be assessed using different assessment methods.
- With respect to **section No.10**, teachers need to ensure to create opportunities and provisions for **co-curricular activities**.

## 12. SUGGESTED MICRO-PROJECTS

**Only one micro-project** is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should **not exceed three**.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **14-16 (fourteen to sixteen) student engagement hours** during the course. The students ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

- a) Prepare a small useful product like various machining parts assembly/v-block/ cutting tools/work holding devices/small laboratory equipment/set-up utilizing laboratory resources.
- b) Using Drafting software, prepare machining products drawing with tolerances, quality measure.
- c) Survey/Visit nearby vendor CNC machine. machining process and prepare report on products manufacture.
- d) Maintenance of available infrastructure related to.

## 13. SUGGESTED LEARNING RESOURCES

Sr. No	Title of Book	Author	Publication with place, year and ISBN
1	CNC Programming handbook	Peter Samid	0-8311-3347-3
2	CNC Fundamentals And Programming	P. M. Agrawal, Dr. V. J. Patel	9789385039553
3	Additive Manufacturing	Andreas Gebhardt, Jan-Steffen Hötter	9781569905821

## 14. SOFTWARE/LEARNING WEBSITES

- i. <https://nptel.ac.in/courses/112105211>(Computer numerical control (CNC) of machine tools and processes)
- ii. <https://www.cnctrainingcentre.com/>
- iii. <https://www.youtube.com/watch?v= kLTM-3mTE8> (Axis Designation)
- iv. <https://www.youtube.com/watch?v=4SZ0PtO79Mg> (G Code)
- v. [https://www.youtube.com/watch?v=tJCm6VR\\_xoM](https://www.youtube.com/watch?v=tJCm6VR_xoM) (M Code)
- vi. <https://www.youtube.com/watch?v=PFj6lNxSJ4w> (Part Programming)
- vii. <https://www.youtube.com/watch?v=3ZIWaeRMLI> (tool compensation)

## 15. PO-COMPETENCY-CO MAPPING

Semester IV	CNC Machines and 3D Printing (4344105)
	POs

Competency & Course Outcomes	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
	Basic & Discipline specific knowledge	Problem Analysis	Design/ development of solutions	Engineering Tools, Experimentation & Testing	Engineering practices for society, sustainability & environment	Project Management	Life-long Learning
CO 1. To demonstrate the working of a CNC machine	2	--	--	3	2	--	2
CO 2. Develop the part program and simulation of the part program in a CNC Machine.	3	3	3	2	3	2	3
CO 3. To demonstrate interface software between CAD and CAM for auto part programming	3	3	3	2	--	--	3
CO 4. Expose the students to different types of Rapid prototyping processes, materials used in RP systems.	2	2	2	--	3	2	2

Legend: '3' for high, '2' for medium, '1' for low and '-' for no correlation of each CO with PO.

#### 16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

##### GTU Resource Persons

Sr. No	Name and Designation	Institute	Contact No.	Email
1.	Muhammad Azharuddin U Badi, Lecturer in Mechanical Engg.	Government Polytechnic, Porbandar	9558800951	<a href="mailto:muhammadabdi92@gmail.com">muhammadabdi92@gmail.com</a>
2.	Meraman P Nandaniya, Lecturer in Mechanical Engg.	Government Polytechnic, Porbandar	9722050778	<a href="mailto:nandaniyamp@gmail.com">nandaniyamp@gmail.com</a>

##### BOS Resource Persons

Sr. No.	Name and Designation	Department	Contact No.	Email
1.	Dr.S.H.Sundarani BOS Chairman HOD Mechanical Engg.	Government Polytechnic Ahmadabad	9227200147	<a href="mailto:gpasiraj@gmail.com">gpasiraj@gmail.com</a>
2.	Dr.Rakesh.D.Patel BOS Member HOD Mechanical Engg.	B.&B. Institute of Technology V V Nagar	9825523982	<a href="mailto:rakeshgtu@gmail.com">rakeshgtu@gmail.com</a>