GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: Manufacturing / Production
Subject Code: BE05000611
Subject Name: Additive Manufacturing

w. e. f. Academic Year:	2025-26
Semester:	5
Category of the Course:	Professional Elective Course - 2

Prerequisite:	Nil
Rationale:	Additive Manufacturing (AM) is a rapidly evolving technology that enables the fabrication of complex components through a layer-by-layer approach, offering significant advantages over conventional manufacturing methods. The growing demand for customization, reduced material waste, and shorter product development cycles has made AM an essential part of modern engineering practices. This subject introduces students to the fundamentals of various AM processes, including liquid-, solid-, and powder-based techniques, along with their materials, tooling, and applications. It also covers CAD integration, reverse engineering, and data processing required for efficient AM workflows. Emphasis is placed on understanding material properties, process selection, and design considerations for manufacturing. Additionally, the course highlights emerging applications such as medical and bio-additive manufacturing. By studying this subject, students gain the knowledge and skills necessary to apply advanced manufacturing technologies in industry, research, and innovation-driven environments.

Course Outcomes:

Sr. No.	CO statement	Marks% weightage
CO-1	Develop integrated workflows combining CAD modeling, reverse engineering, and data preparation for efficient additive manufacturing.	15
CO-2	Compare liquid-based and solid-based additive manufacturing systems based on process characteristics, material usage, advantages, and limitations.	25
CO-3	Evaluate and select appropriate powder-based additive manufacturing processes for engineering components based on material, accuracy, and functional requirements.	20
CO-4	Select suitable materials and powder processing routes for additive manufacturing applications based on design, mechanical properties, and end-use requirements.	25
CO-5	Explain the concepts of medical and bio-additive manufacturing, including customized implants and prosthesis design and production.	15

Teaching and Examination Scheme:

Teaching / Learning Scheme (in Hours per semester)					Total Credits	Assessment Pattern and Marks					Total Marks
						Theory		Tutorial / Practical			
L	T	P	PBL	Total no of hours per semester		ESE (E)	PA / CA (M)	PA/CA (I)	PBL (I)	ESE (V)	
45	0	30	15	90	3	70	30	20	30	50	200

**** Problem-Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.***

Content:

Sr. No.	Content	Total Hrs
1	**Introduction:** Overview, History, Need and Classification of Additive Manufacturing, Additive Manufacturing Technology in Product Development, Materials for Additive Manufacturing Technology, Tooling, Applications.	04
2	**CAD & Reverse Engineering:** Basic Concept, Digitization techniques, Model Reconstruction, Data Processing for Additive Manufacturing Technology: CAD model preparation, Part Orientation and support generation, Model Slicing, Tool path Generation, Softwares for Additive Manufacturing Technology: MIMICS, MAGICS.	08
3	**Liquid and Solid Based Additive Manufacturing:** Classification, Liquid based system, Stereolithography Apparatus (SLA): Principle, process, advantages and applications. Solid based system, Fused Deposition Modelling: Principle, process, advantages and applications, Laminated Object Manufacturing.	08
4	**Powder based Additive Manufacturing:** Selective Laser Sintering, Principles of SLS process, Process, advantages and applications, Three-Dimensional Printing: Principle, process, advantages and applications. Laser Engineered Net Shaping (LENS), Electron Beam Melting.	6
5	**Additive Manufacturing Materials:** FDM: ABS (acrylonitrile butadiene styrene), PLA (polylactic acid), PETG (polyethylene terephthalate glycol), Nylon, TPU (thermoplastic polyurethane), PVA (polyvinyl alcohol), HIPS (high impact polystyrene), Composites (carbon fiber, kevlar, fiberglass). SLA: Types of resin (Standard Resins, Clear Resin, Draft Resin, Tough and Durable Resins, Rigid Resins, High Temp Resin, Flexible and Elastic Resins, Medical and dental resins, Jewelry resins, Ceramic resin). SLS: Nylon 12, Nylon 11, TPU, Nylon composites, structure, properties and applications. Metal 3D Printing Materials: Structure, properties and applications of Titanium, Stainless steel, Aluminum, Tool steel, Nickel alloys, Powder materials: Introduction and History of Powder Metallurgy (PM), Present and Future Trends of PM, Powder Production Techniques, Different Mechanical and Chemical methods, Atomization of Powder, other emerging processes, Performance Evaluation of different Processes, Design & Selection of Process. Microstructure Control in Powder, Powder Shaping, Ceramics Sintering, Sintering of Single & Mixed Phase Powder, Liquid Phase Sintering.	12

6	**Medical and Bio-Additive Manufacturing:** Customized implants and prosthesis: Design and production. Bio-Additive Manufacturing- Computer Aided Tissue Engineering (CATE), Case studies	**7**
	TOTAL	**45**

Suggested Specification table with Marks (Theory): (For B.E. only)

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	**20**	**25**	**15**	**10**	**10**

R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

The syllabus of Additive Manufacturing directly contributes to

SDG 3	**Good health and well-being**
SDG 4	**Quality Education**
SDG 9	**Industry, Innovation and Infrastructure**
SDG 11	**Sustainable Cities and Communities**
SDG 12	**Responsible Consumption and Production**

Reference Books:

1. Dongdong Gu, Laser Additive Manufacturing of High-Performance Materials, Springer, 2015.
2. G Odian Principles of Polymerization, Wiley Inerscience John Wiley and Sons, 4th edition, 2005.
3. Ian Gibson, David W Rosen, Brent Stucker., "Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing", 2nd Edition, Springer, 2015.
4. Li Yang, Keng Hsu, Brian Baughman Donald Godfrey, Francisco Medina, Mambally kalathil Menon Soeren Wiener, Additive Manufacturing of Metals: The Technology, Materials, Design and Production, Springer, 2017.
5. Chua C.K., Leong K.F., and Lim C.S., "Rapid prototyping: Principles and applications", Third Edition, World Scientific Publishers, 2010.
6. Gebhardt A., "Rapid prototyping", Hanser Gardener Publications, 2003.
7. Liou L.W. and Liou F.W., "Rapid Prototyping and Engineering applications: A tool box for prototype development", CRC Press, 2007.
8. Kamrani A.K. and Nasr E.A., "Rapid Prototyping: Theory and practice", Springer, 2006.
9. Hilton P.D. and Jacobs P.F., "Rapid Tooling: Technologies and Industrial Applications", CRC press, 2000.

Standards and Act:

1. **ISO/ASTM 52900** – Terminology & basic principles

2. **ISO/ASTM 52915** – Additive Manufacturing File Format (AMF)
3. **ASTM F3049** – Metal powders for AM
4. **3MF / AMF file formats** for CAD–AM integration

List of Experiments:

1. Study and demonstration of different additive manufacturing systems (FDM, SLA, SLS) and their components.
2. Preparation of a basic 3D CAD model using any CAD software for additive manufacturing.
3. Conversion of CAD model into STL format and analysis of STL file errors (mesh repair).
4. Study of part orientation and support structure generation using slicing software.
5. Model slicing and generation of G-code/tool path for 3D printing.
6. Fabrication of a simple component using Fused Deposition Modelling and study of process parameters.
7. Comparative study of different materials used in FDM (PLA, ABS, PETG) through sample printing.
8. Study and demonstration of Stereolithography Apparatus process and post-processing techniques.
9. Reverse engineering of a simple component using 3D scanning/digitization and reconstruction of CAD model.
10. Study of powder-based AM processes such as Selective Laser Sintering through simulation or video/demo.
11. Measurement and inspection of printed parts (dimensional accuracy, surface finish).
12. Case study/practical on application of additive manufacturing in medical or industrial field (report/presentation).

Major Equipment:

3D Printing Machine

List of Open Source Software

1. AutoCAD
2. SolidWorks
3. CATIA
4. Fusion 360
5. Geomagic Design X
6. MIMICS
7. MAGICS
8. ANSYS Additive

List of learning website:

1. **http://nptel.ac.in/courses/**

Note:

List of suggested activities for Problem-based Learning (PBL):

Sr. No.	PBL category	Name of the activity	No. of hours	Evaluation Criteria
1.	Complex Problem-Solving targeting	Mini Project	15h (need to be changed as per total	Based on the novelty of project, technical

	relevant SDGs / Mini Project		PBL hours)	understanding, report quality and presentation
2.	Case Study Analysis / Seminar	Seminar	15h (need to be changed as per total PBL hours)	Based on the quality of report and presentation, technical understanding
3.	Micro project	Micro project	8h (need to be changed as per total PBL hours)	Based on the novelty of project, technical understanding, quality of report and demonstration
4.	Industry/Research laboratory visit	Industry/Research laboratory visit	Visit = 5h, Report preparation = 5h Total = 10h	Based on report submitted. Report should contain observations and calculations based on industry/ lab data.
5.	Video Based Learning	Technical video-based learning related to the subject	Duration of video = 5h Report preparation = 5h Total = 10h	Report /presentation based on the video learning outcomes.
6.	Assignment / Technical Writing / Research Writing	Assignment writing. Numerical based assignment is preferable.	5 assignments of 4 h each Total = 20h	Based on the correctness of submitted assignment
7.	Group Discussion / Quiz / Simulation	Problem solving/Coding using C, C++, MATLAB, Python, SCILAB, modeling and Analysis software or any other software	5 small coding-based assignment of 2h each Total = 10h	Based on the coding solution submitted.
8.	Video Based Learning	Self-learning online course	Minimum duration of the course should be 10h	Examination based assessment at the end of course. Based on the certificate produced.
9.	Complex Problem-Solving targeting relevant SDGs / Mini Project	Identification and solution of Complex problem	Maximum 2 problems. Study of the problem and solution finding, Total = 10h	Based on the depth of the solution submitted.
10.	Video Based Learning	Videos on Industrial safety/Disaster Management aspects based on subject	Duration of video = 5h Report preparation = 5h Total = 10h	Based on quiz/report submitted
11.	Research Paper Review / Analysis	Technical paper reading and	5 research papers = 20h	Summarize research paper and evaluation critical

		summarization of research papers based on relevant subject		parameters
12.	Poster / Chart / PowerPoint presentation	Poster/chart/power point preparation on technical topics	Duration = 6h	Based on poster/chart preparation and presentation skills
13.	Industry/Research laboratory visit	Industrial exposure for 2-3 days to observe and provide tentative solutions on society/environment/health/sustainability/any other issue	Duration = 15h for industrial exposure Problem identification and tentative solution = 10h Total = 20h	Based on evaluation of critical problems and solutions
14.	Group Discussion / Quiz / Simulation	Group Discussion on emerging/trending technical topics based on subject	Duration = 1h – 3h per topic	Based on performance in group discussion, technical depth, knowledge etc.
15.	Case Study Analysis / Seminar	Real world case studies-based learning	Duration of data collection/study = 5h Report preparation = 5h Total = 10h	Based on in-depth study, technical depth, data collected, fact finding, etc.
16.	Group Discussion / Quiz / Simulation	Application/Software development	Duration = 10h	Depending on the complexity of the Application/Software
17.	Assignment / Technical Writing / Research Writing	Research paper publication	Duration = 10h	Based on submission of proof of publication
18.	Micro project	Upgradation/Reverse engineering studies of existing equipment of the laboratory	Duration 10h	Based on the performance of the equipment
19.	Industry/Research laboratory visit	Expert lecture/session	Duration 3h For attending the lecture/session– 2h and for report writing 1h	Based on the proof of attendance and report submitted
20.	Video Based Learning	Annotated Video Explanation of Concept/Problem	10h (Preparation + Recording + Submission)	Based on accuracy of explanation, clarity, and presentation style.
21.	Assignment / Technical Writing / Research Writing	Patent Search and Innovation Gap Identification	10h (Search + Report)	Based on number of relevant patents analyzed and identification of innovation scope.
22.	Assignment /	Preparation of a report	10h (study of Indian	Based on report quality

	Technical Writing / Research Writing	on Indian Standard(s)	Standard(s) + report	and understanding of the relevant Indian Standard(s).

Note:

1. In alignment with Outcome-Based Education (OBE) and NBA accreditation requirements, the subject **Additive Manufacturing compulsorily incorporates Micro Project with 05 marks as PBL activities.**
   These activities are incorporated as integral Project-Based Learning (PBL) components. These activities are designed to foster experiential learning, encourage innovation, and strengthen problem-solving skills by engaging students in practical applications of power converter design, simulation, and analysis. The inclusion of PBL ensures that learners develop higher-order cognitive abilities mapped to Bloom's taxonomy, while simultaneously enhancing teamwork, communication, and research competencies essential for professional engineering practice.
2. The hours allocated to specific activities should be proportionate to the total no. of PBL hours and marks.
3. All the suggested activity should be related to the subject.
4. The number of hours is suggestive. Faculty can sub-divide the number of hours based on the activity. However, total number of hours is fixed.
5. Rubrics for the evaluation can be prepared by the faculty.
6. Subject teacher can add the relevant activities other than those listed above, with the consent of head of the department and DQAC.

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