Savitribai Phule Pune University, Pune

Maharashtra, India

Faculty of Science and Technology

Board of Studies (BoS)
Mechanical and Automobile Engineering

NEP 2020

Honors Program in
Additive Manufacturing

(18 Credits)

2024 PATTERN

(w.e.f Academic Year: 2026-27)

Website: https://www.unipune.ac.in/

Contents

Semester: V, VI, VII & VIII Courses (Additive Manufacturing)

NOMENCLATURE

AEC	Ability Enhancement Courses
AICTE	All India Council for Technical Education
CO	Course Outcome
CEP	Community Engagement Project
CCE	Comprehensive Continuous Evaluation
HSSM	Humanities, Social Science, and Management
MDM	Multidisciplinary Minor
MEC	Mechanical Engineering
MOOC	Massive Open Online Course
NPTEL	National Programme on Technology Enhanced Learning
NEP	National Education Policy
PCC	Program Core Course
PEO	Program Educational Objectives
PSO	Program Specific Objectives
SWAYAM	Study Webs of Active-learning for Young Aspiring Minds
UGC	University Grants Commission
VEC	Value Education Course
VSE	Vocational and Skill Enhancement Course
WK	Knowledge and Attitude Profile

PREFACE BY BOARD OF STUDIES

Dear Students and Teachers,

We, the members of the Board of Studies – Mechanical Engineering, are very happy to present the Third-Year Mechanical Engineering syllabus, effective from the **Academic Year 2026–27 (2024 Pattern).** We are confident that you will find this syllabus both interesting and challenging. The present curriculum will be implemented for Third Year Engineering from the academic year 2026–27, and it will be subsequently extended to the Final Years in the academic years **2027–28**.

Mechanical Engineering is one of the most sought-after branches among engineering students, which necessitates continuous revision and up gradation of the syllabus. Mechanical Engineering is a dynamic discipline that integrates principles from core engineering fields and supports innovation across manufacturing, design, energy, materials, and automation. This curriculum is designed to provide students with a comprehensive understanding of the fundamentals, emerging technologies, and practical applications in Mechanical Engineering, while also equipping them to meet the demands of a rapidly evolving industry.

The revised syllabus aligns with the vision of **NEP-2020**, and conforms to the frameworks set by Savitribai Phule Pune University, AICTE New Delhi, UGC, and various accreditation agencies. It takes into account recent technological developments, innovations, and industry needs to ensure students are well- prepared for professional challenges.

Wherever applicable, additional learning resources such as NPTEL and SWAYAM links are provided at the end of each course. Students are encouraged to utilize these platforms for self-learning, engage in online courses, and undertake additional projects to enhance their knowledge and skill set. On successful completion, they are advised to submit their course certifications, which will further support and enrich their academic growth.

This curriculum is the result of collaborative efforts involving academic experts, industry professionals, and alumni to ensure relevance and excellence. It is designed not only to meet current industry expectations but also to prepare students for higher studies, research, and entrepreneurial ventures in the field of Mechanical Engineering.

We hope this curriculum inspires students to become technically competent professionals, responsible citizens, and contributors to the technological and sustainable advancement of society.

Dr. Pradeep A. Patil
Chairman
Board of Studies - Mechanical Engineering

PROGRAM SPECIFIC OUTCOMES

PSO1 : **SPECIFY, DESIGN** and **EVALUATE** mechanical components and systems using modelling and analysis software.

PSO2 : **APPLY** knowledge of machines, tools, automation, properties of advanced materials and modern management methods for manufacturing of mechanical components and systems.

PSO3 : **APPLY** core aspects of thermal and fluid engineering to determine the performance of mechanical systems including power absorbing and power generating systems.

PROGRAM EDUCATIONAL OBJECTIVES

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing a graduate to achieve.

PEO1 : The graduate will have a successful career in mechanical engineering with strong technical, research & professional skills.

PEO2 : The graduate will possess an ability to work in diversified fields along with team work and leadership qualities.

PEO3 : The graduate will continue to learn and to adapt in a society of constantly evolving technological environment

PROGRAM OUTCOMES

Program Outcomes (POs) are statements that articulate what students are expected to know, understand, and be able to do by the time they graduate from the program. These outcomes are aligned with the overall educational objectives of the program and reflect the skills, knowledge, attitudes, and behaviors acquired by students throughout their academic journey. On successful completion of B.E. in Mechanical Engineering, graduating students/graduates will be able to:

PO No.	Title	Program Outcome Description
PO1	Engineering Knowledge	Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop the solution of complex engineering problems.
PO2	Problem Analysis	Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
PO3	Design / Development of Solutions	Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for public health and safety, whole-life cost, net zero carbon, culture, society and environment. (WK5)
PO4	Conduct Investigations of Complex Problems	Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)
PO5	Engineering Tool Usage	Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling, recognizing their limitations to solve complex engineering problems. (WK2 and WK6)
PO6	The Engineer and The World	Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7)
PO7	Ethics	Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
PO8	Individual and Collaborative Team Work	Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
PO9	Communication	Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences.
PO10	Project Management and Finance	Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects in multidisciplinary environments.
PO11	Life-Long Learning	Recognize the need for, and have the preparation and ability for: (i) independent and life-long learning, (ii) adaptability to new and emerging technologies, and (iii) critical thinking in the broadest context of technological change. (WK8)

KNOWLEDGE AND ATTITUDE PROFILE (WK)

WK No.	Focus Area	Description
WK1	Natural Sciences and Social Sciences	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.
WK2	Mathematics and Data Analysis	Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.
WK3	Engineering Fundamentals	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	Engineering Specialist Knowledge	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
WK5	Engineering Design and Environmental Considerations	Knowledge, including efficient resource use, environmental impacts, whole- life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.
WK6	Engineering Practice (Technology)	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK7	Role of Engineering in Society	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Research and Critical Thinking	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.
WK9	Ethics and Inclusive Behavior	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability, etc., with mutual respect.

Reference: Self-Assessment Report (SAR) Format Undergraduate Engineering Programs Graduate Attributes and Professional Competencies Version 4.0 (GAPC V4.0) - (August 2024) Page 55-56

GENERAL RULES AND GUIDELINES

Term	Definition
Course Outcomes (COs)	Course Outcomes are narrower statements that describe what students are expected to know and be able to do at the end of each course. These relate to the skills, knowledge, and behavior that students acquire throughout the course.
Assessment	Assessment is one or more processes, carried out by the institution, that identify, collect, and prepare data to evaluate the achievement of **Program Educational Objectives (PEOs)** and **Program Outcomes (POs)**.
Evaluation	Evaluation is one or more processes, performed by the **Evaluation Team**, to interpret the data and evidence gathered through assessment practices. It determines how well PEOs or POs are being achieved, and informs decisions for improvement.

ASSESSMENT AND EVALUATION:

Assessment and Evaluation shall be conducted in two parts:
1. Comprehensive Continuous Evaluation (CCE)
2. End-Semester Examination (ESE)

Component	Description	Marks
Comprehensive Continuous Evaluation (CCE)	Conducted at institute level, covering all Units of the syllabus. The design and mark allocation follow the Continuous Assessment Sheet structure.	30
End-Semester Examination (ESE)	Conducted at university level, typically covering the entire syllabus through summative examination.	70
	Total Marks per Subject	**100**

A) <u>Comprehensive Continuous Evaluation (CCE) :</u>

CCE to be conducted either on the basis of Mode 1 or Mode 2.

CCE MODE 1:

To design a Comprehensive Continuous Evaluation (CCE) scheme for a theory subject of 15 or 30 marks with the specified parameters, the allocation of marks and the structure can be as per continuous assessment sheet;

Savitribai Phule Pune University
Board of Studies (Mechanical and Automobile Engineering)
Comprehensive Continous Evaluation (CCE) [30 Marks Distribution]

Class: TE- Mechanical Engineering — Subject: Refrigeration and Air Conditioning

Exam Seat No.	Roll No.	Name of Student	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Cumulative Sum				30 Marks Distribution				Marks obtained out
			Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Internal Test	Attendance	Field Activity	Quiz	Internal Test	Attendance	
			A	B	C	D	E	F	G	H	I	J	SUM(A+C+E+G+I)	SUM(B+D+F+H+J)			P	Q	R	S	SUM(P:S)
			10	10	10	10	10	10	10	10	10	10	50	50	100	100	15	5	5	5	30
T9028246474	2020	MAAN PANCHAL	8	8	8	8	8	8	8	8	8	8	40	40	60	75	12	4	3	3.8	22.75

Figure 1 Template Comprehensive Continuous Evaluation (CCE) ***Click*** *here to download .*

Field Activities / Home Assignments

Field activities and home assignments are essential components of experiential learning. Under this head, course projects, industrial visits, and guest lectures are to be incorporated. For each unit, one such activity should be designed and executed to reinforce theoretical learning through practical exposure.

1. **Course Projects**

   Course Projects should be framed based on real-world problems relevant to the subject. Each course project must be communicated through one of the following modes. It is recommended to complete all the communication modes across different course projects:

- **Poster Presentation**
- **PowerPoint Presentation**
- **Model Making**
- **Field or Survey Report with Oral Presentation** (e.g., case study)
- **Submission of Digital Content (e.g. Video Summary)**

To evaluate these field activities, **assessment rubrics** should be designed. The rubrics should include criteria such as clarity, innovation, subject relevance, presentation skills, and technical content.

Note: Part of work of any co-curricular activities (relevant to subject contents) like national level project competitions, club activities, paper presentations, startup activities can be accepted as a course projects.

2. **Industrial Visit**

An industrial visit should be planned in alignment with the subject's scope and should particularly address advancements in the respective field. The purpose is to provide students exposure to actual engineering practices and systems.

Assessment of industrial visits should be carried out using any of the following tools:

- Quiz (based on the visit)
- Interactive video or oral discussion
- Submission of a detailed visit report

3. **Guest Lectures**

Guest lectures should be relevant to the course and highlight advanced topics or recent trends in the field. Subject experts from academia or industry may be invited.

Assessment methods for guest lectures may include:

- Quiz conducted post-lecture
- Attendance monitoring
- Evaluation of attentiveness and participation

Rubrics can be developed, if possible, to objectively assess student involvement in guest lectures.

4. **Quiz**

Unit-wise quizzes should be planned and can be conducted either **online** (Via LMS, Google Forms) or **offline**. Each quiz should include a **pool of 20 questions**, from which **students are required to attempt any 10**.

The quizzes should be diversified across the following question types:

- Simple Multiple Choice Questions (MCQs)
- Numerical MCQs
- Image-based Questions
- Match the Following
- Fill in the Blanks
- Drag and Drop (using images or words)

This variety ensures the assessment caters to different cognitive skills and learning styles.

5. **Internal Tests**

Two major internal tests should be conducted as follows:

1. **Midterm Examination**: This should cover **Unit I and Unit II**, and should include questions targeting **Bloom's Taxonomy Levels 2, 3, and 4** (UNDERSTAND, APPLY, and ANALYZE).
2. **End term Examination**: This should cover the **remaining units** and should also include questions mapped to **BL Levels 2, 3, and 4**.

CCE MODE 2:

Comprehensive Continuous Evaluation scheme in this mode for a theory subject of **30 marks** with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr. No.	Parameters	Marks	Coverage of Units
1	Unit Test	12 Marks	Unit 1 & Unit 2 (6 Marks/Unit)
2	Assignments/Case Study	12 Marks	Unit 3 & Unit 4 (6 Marks/Unit)
3	Seminar Presentation/ Open Book Test/ Quiz	06 Marks	Unit 5

- **Unit Test–**

Format: Questions designed as per Bloom's Taxonomy guidelines to assess various cognitive levels (Remember, Understand, Apply, Analyze, Evaluate, and Create).

Implementation: Schedule the test after completing Units 1 and 2. Ensure the question paper is balanced and covers key concepts and applications.

- **Sample Question Distribution**–
  1. Remembering (2 Marks): Define key terms related to [Topic from Units 1 and 2].
  2. Understanding (2 Marks): Explain the principle of [Concept] in [Context].
  3. Applying (2 Marks): Demonstrate how [Concept] can be used in [Scenario]
  4. Analyzing (3 Marks): Compare & contrast [Two related concepts] from Units 1 and 2
  5. Evaluating (3 Marks): Evaluate the effectiveness of [Theory/Model] in [Situation].
- **Assignments / Case Study:** Students should submit one assignment or one Case Study Report based on Unit 3 and one assignment or one Case Study Report based on Unit 4.

  – ***Format***: Problem-solving tasks, theoretical questions, practical exercises, or case studies that require in-depth analysis and application of concepts.

  – ***Implementation:*** Distribute the assignments or case study after covering Units 3 and 4. Provide clear guidelines and a rubric for evaluation.
- **Seminar Presentation: –**

  Format: Oral presentation on a topic from Unit 5, followed by a Q&A session.

  Deliverables**:** Presentation slides, a summary report in 2 to 3 pages, and performance during the presentation

  Implementation: Schedule the seminar presentations towards the end of the course. Provide students with ample time to prepare and offer guidance on presentation skills.
- **Open Book Test: –**

  Format: Analytical and application-based questions to assess depth of understanding. – **Implementation**: Schedule the open book test towards the end of the course, ensuring it covers critical aspects of Unit 5
- **Quiz:** –

  Format: Quizzes can help your students practice existing knowledge while stimulating interest in learning about new topic in that course. You can set your quizzes to be completed individually or in small groups.

  Implementation**:** Online tools and software can be used create quiz. Each quiz is made up of a variety of question types including multiple choice, missing words, true or false etc
- **Example Timeline for conducting CCE: –**
  1. Weeks 1-4 : Cover Units 1 and 2
  2. Week 5 : Conduct Unit Test (12 marks)
  3. Weeks 6-8 : Cover Units 3 and 4
  4. Week 9 : Distribute and collect Assignments / Case Study (12 marks)
  5. Weeks 10-12 : Cover Unit 5
  6. Week 13 : Conduct Seminar Presentations or Open Book Test or Quiz (6 marks)

- **Evaluation and Feedback: –**
    1. **Unit Test:** Evaluate promptly and provide constructive feedback on strengths and areas for improvement.
    2. **Assignments / Case Study:** Assess the quality of submissions based on the provided rubric. Offer feedback to help students understand their performance.
    3. **Seminar Presentation:** Evaluate based on content, delivery, and engagement during the Q&A session. Provide feedback on presentation skills and comprehension of the topic.
    4. **Open Book Test:** Evaluate based on the depth of analysis and application of concepts. Provide feedback on critical thinking and problem-solving skills.

B) <u>End-Semester Examination (ESE)</u>

Detailed Scheme for 60 Marks: Unit-Wise Allocation (12 Marks per Unit): Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation.

Detailed Scheme for 40 Marks: Unit-Wise Allocation (08 Marks per Unit): Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation The following structure is to be followed for designing an ESE for a **theory subject of 60 marks** covering **all 5 units** of the syllabus, with **questions set as per Bloom's Taxonomy** guidelines and **12 marks allocated per unit**.

2. Balanced Coverage

Ensure balanced coverage of all units with questions that assess different **cognitive levels of Bloom's Taxonomy**:

a) **Remembering**: Basic recall of facts and concepts.
b) **Understanding**: Explanation of ideas or concepts.
c) **Applying**: Use of information in new situations.
d) **Analyzing**: Drawing connections among ideas.
e) **Evaluating**: Justifying a decision or course of action.
f) **Creating**: Producing new or original work (if applicable).

Curriculum Structure
Honor Courses (2024 Pattern)
NEP 2020 Compliant Curriculum Structure

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Third and Final Year Mechanical Engineering (2024 pattern)

Course Code	Course Type	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credits			
			L	T	P	CCE	ESE	TW	OR	PR	TOTAL	L	T	P	TOTAL
Semester-V															
HADM301MEC	Honor Course	Additive Manufacturing Technology		3		30	70				100		3		4
HADM302MEC	Honor Course	Modelling Lab			1			50			50			1	
Semester-VI															
HADM351MEC	Honor Course	Design for Additive Manufacturing		3		30	70				100		3		4
HADM352MEC	Honor Course	3D Printing Lab			1			50			50			1	
Semester-VII															
HADM401MEC	Honor Course	Additive Manufacturing System Design		3		30	70				100		3		5
HADM402MEC	Honor Course	Seminar			2			50			50			2	
Semester-VIII															
HADM451MEC	Honor Course	3D Printing Applications & Entrepreneurship		3		30	70				100		3		5
HLEA452MEC	Honor Course	Industry Oriented 3D Printing Project			2			50			50			2	
		Total		**12**	**06**	**120**	**280**	**200**			**600**		**12**	**06**	**18**

Savitribai Phule Pune University, Pune

Maharashtra, India

TE - Mechanical Engineering (2024 Pattern)

SEMESTER- V

Honor Courses

[Additive Manufacturing]

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

HADM301MEC: Additive Manufacturing Technology

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End-Semester**	**70 Marks**

- **Prerequisites:** Manufacturing processes, Engineering materials and metallurgy, solid mechanics

Course Objectives:

After completing this course, students will be able to:

1. To introduce the fundamental concepts, terminology, process chain, and classification of Additive Manufacturing technologies.
2. To understand working principles, materials, process parameters, advantages, limitations, and applications of major Additive Manufacturing processes.
3. To develop the ability to select suitable Additive Manufacturing processes for different engineering applications.
4. To familiarize students with industrial applications, emerging trends, and future developments in Additive Manufacturing.
5. To prepare students for advanced courses in Design for Additive Manufacturing, Additive Manufacturing Systems, and industrial applications.

Course Outcomes: On completion of the course, Student will be able to

CO1: Explain the fundamentals, process chain, classification, materials, advantages, and limitations of Additive Manufacturing.

CO2: Describe the working principles and characteristics of extrusion-based and photo polymerization-based Additive Manufacturing processes.

CO3: Explain powder bed fusion, laser-based, inkjet-based, and directed energy deposition technologies.

CO4: Select an appropriate Additive Manufacturing process based on material, product requirements, and engineering applications.

CO5: Discuss industrial applications, emerging trends, and future opportunities in Additive Manufacturing.

Course Contents

Unit I	Additive Manufacturing (AM) Overview	(08 Hours)

Introduction to Additive Manufacturing, Historical Development, Additive Manufacturing versus Conventional Manufacturing, Role of AM in Product Development Cycle, Rapid Prototyping, Relevance of AM in Industry 4.0, AM Process Chain, Advantages and Limitations, Types of Materials, Classification of AM Processes (Process-based, Material Form-based and Application-based), and Process Planning for Additive Manufacturing.

CCE Activities:

- Comparative study of Additive Manufacturing and Conventional Manufacturing.
- Prepare a flowchart of the AM process chain.
- Presentation on the role of Additive Manufacturing in Industry 4.0..

Unit II	**AM Processes and Extrusion-based Deposition Technologies**	**(08 Hours)**

Overview of Additive Manufacturing Processes: Extrusion, Jetting, Photo-polymerization, Powder Bed Fusion, Sheet Lamination and Directed Energy Deposition. Study of Process, Materials, Process Parameters, Advantages, Limitations and Applications of Extrusion-based Deposition Technologies including Fused Deposition Modelling (FDM), Fused Filament Fabrication (FFF), Direct Ink Writing (DIW) and Robocasting.

CCE Activities:

- Comparative study of FDM and FFF.
- Demonstration of an FDM printer.
- Report on one extrusion-based AM system.

Unit III	**Light-Based Photo-curing and Laser-Based Melting Technologies**	**(08 Hours)**

Study of Process, Materials, Process Parameters, Advantages, Limitations and Applications of Light-Based Photo-curing Technologies including SLA, DLP and CLIP. Study of Laser-Based Melting Technologies including SLS, DMLS, SLM, EBM and LENS

CCE Activities:

- Comparative study of SLA and DLP.
- Seminar on Metal Additive Manufacturing.
- Case study on one laser-based AM process.

Unit IV	**Inkjet (Droplet)-Based Deposition and Fusion Technologies**	**(08 Hours)**

Study of Process, Materials, Process Parameters, Advantages, Limitations and Applications of Multi Jet Modelling (MJM), PolyJet Printing, Binder Jetting, Multi Jet Fusion and Colour Jet Printing (CJP). Introduction to Directed Energy Deposition techniques including Plasma, TIG/MIG, Electron Beam DED and Direct Metal Deposition (DMD).

CCE Activities:

- Assignment on Binder Jetting.
- Presentation on PolyJet technology.
- Report on Directed Energy Deposition.

Unit V	**Case Studies, Applications and Special Topics**	**(08 Hours)**

Applications of Additive Manufacturing in Aerospace, Automotive, Biomedical, Construction, Machine Tools and Consumer Products. Special Topics including 4D Printing, Bioprinting, Biomaterials, Mass Customization and Future Trends in Additive Manufacturing.

CCE Activities:

- Literature survey on an emerging AM application.
- Presentation on future trends in Additive Manufacturing.
- Industrial case study of AM implementation.

Learning Resources

Text Books

1. Chua Chee Kai, Leong Kah Fai, “3D Printing and Additive Manufacturing: Principles & Applications”, 4th Edition, World Scientific, 2015 2.
2. Amit Bandyopadhyay, Susmita Bose, “Additive manufacturing”, CRC Press, Taylor & Francis Group, 2016 3.
3. Ian Gibson, David W. Rosen, Brent Stucker “Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing” Springer, 2010

Reference Books

1. L. Lu, J. Y. H. Fuh and Y.S. Wong, “Laser-Induced Materials and Processes for Rapid Prototyping”, Springer, 2001
2. Andreas Gebhardt and Jan-Steffen Hötter, "Additive Manufacturing: 3D Printing for Prototyping and Manufacturing" Hanser Publishers, Munich, 2016.
3. Ben Redwood, FilemonSchöffer& Brian Garret, "The 3D Printing Handbook: Technologies, design and applications", 3D Hubs B.V. 2017
4. Ehsan Toyserkani, Amir Khajepour, Stephen F. Corbin, “Laser Cladding”, CRC Press, 2004
5. Andreas Gebhardt, “Understanding Additive”, Hanser Publishers, Munich, 2011
6. Ben Redwood, Filemon Schöffer & Brian Garret, “The 3D Printing Handbook – Technologies, Design and Applications” Part One:3D Printing Technologies and Materials, 3D Hubs, 2017
7. Chee Kai, Kah Fai, Chu Sing, ‘Rapid Prototyping: Principles and Applications”, 2003
8. D. T. Pham and S.S. Dimov, “Rapid Manufacturing” Springer, 2001
9. Rupinder Singh J. Paulo Davim, “Additive Manufacturing - Applications and Innovations” CRC Press Taylor& Francis Group, 2019

Web References

1. NPTEL Course on Fundamentals of Additive Manufacturing Technologies by Prof. SajanKapil, IIT Guwahati, https://onlinecourses.nptel.ac.in/noc21_me115/preview
2. Introduction to Additive Manufacturing, https://www.youtube.com/watch?v=LCQoi10cGTo NPTEL IIT Kanpur, “Rapid Manufacturing”, Dt. Janakarajan
3. Fundamentals of Additive Manufacturing Technologies [Intro Video]
4. Laser Based Manufacturing [Intro Video]
5. Additive Manufacturing (History ,Advantage ,Disadvantage and Application)
6. Design for Additive Manufacturing: The Impact of Design on AM Technologies

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

HADM302MEC: Modelling Laboratory

Teaching Scheme		Credit	Examination Scheme	
Theory	NA	1	ESE	NA
Practical	2 Hours/Week		TW	50 Marks

- **Prerequisites:** Engineering Graphics, Solid Modelling & Drafting

Course Objectives:

After completing this course, students will be able to:

1. Apply Conceptual Design and Geometric Modeling for AM
2. Manipulate various Data formats
3. Convert part file into STL format and Repair using different software tools
4. Determine part orientation for minimum build time and part errors

Course Outcomes:

On completion of the course, learner will be able to

CO1. DEVELOP CAD models for 3D printing, Select and use correct CAD formats in the manufacture of 3D printed parts

CO2. IMPORT and Export CAD data and generate STL file/s

CO3. IDENTIFY STL file problems and apply Repair Algorithms

CO4. DEVELOP STL file for CAD models with appropriate Support Structures and Orientation

CO5. APPLY techniques of CAD and Reverse Engineering for Geometry Transformation

Guidelines for Laboratory Conduction

The student shall complete the following hands-on activities as a Term Work under the guidance of concerned faculty member. The open source software shall be preferred for conduction of practical

Term Work

The learner shall complete minimum 08 of the following activities as a Term-Work:

List of Practical

1. Identification of a product for Additive Manufacturing and its Geometric Modeling
2. Working with CAD Data Exchange formats
3. Slicing of corrected STL files
4. Identification of problems associated with STL file
5. Object Scanning using 3D Scanner
6. Conversion of CT/MRI Medical scan data into STL file
7. Application of Repair Algorithms to make error-free CAD models
8. Part orientation, Support structure and Tool Path generation
9. Estimation of Build-time and Material for Model and Support structure generation
10. Simulation for optimization of Build-time and Material consumption
11. Generation of Tool Path data for 3D Printing of the physical part on RP machine
12. Industrial Visit and Report on visit to AM facility

Learning Resources

Text Books

1. Chua Chee Kai, Leong Kah Fai, "3D Printing and Additive Manufacturing: Principles & Applications", 4th Edition, World Scientific, 2015 2.
2. Amit Bandyopadhyay, Susmita Bose, "Additive manufacturing", CRC Press, Taylor & Francis Group, 2016 3.
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6. Ben Redwood, Filemon Schöffer & Brian Garret, "The 3D Printing Handbook – Technologies, Design and Applications" Part One:3D Printing Technologies and Materials, 3D Hubs, 2017
7. Chee Kai, Kah Fai, Chu Sing, 'Rapid Prototyping: Principles and Applications", 2003
8. D. T. Pham and S.S. Dimov, "Rapid Manufacturing" Springer, 2001
9. Rupinder Singh J. Paulo Davim, "Additive Manufacturing - Applications and Innovations" CRC Press Taylor& Francis Group, 2019

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7. NPTEL Course on Fundamentals of Additive Manufacturing Technologies by Prof. SajanKapil, IIT Guwahati, https://onlinecourses.nptel.ac.in/noc21_me115/preview
8. Introduction to Additive Manufacturing, https://www.youtube.com/watch?v=LCQoi10cGTo NPTEL IIT Kanpur, "Rapid Manufacturing", Dt. Janakarajan
9. Fundamentals of Additive Manufacturing Technologies [Intro Video]
10. Laser Based Manufacturing [Intro Video]
11. Additive Manufacturing (History ,Advantage ,Disadvantage and Application)

Savitribai Phule Pune University, Pune

Maharashtra, India

TE - Mechanical Engineering (2024 Pattern)

SEMESTER- VI

Honor Courses

[Additive Manufacturing]

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

HADM351MEC: Design for Additive Manufacturing

Teaching Scheme		Credit	Examination Scheme	
Theory	3 Hours/Week	3	CCE	30 Marks
Practical	NA		End-Semester	70 Marks

- **Prerequisites:** Manufacturing processes I & II, Engineering materials and metallurgy, solid mechanics, Additive Manufacturing Technology

Course Objectives:
After completing this course, students will be able to:
1. To understand the principles and methodology of Design for Additive Manufacturing (DfAM).
2. To learn design guidelines, material considerations, and process planning for Additive Manufacturing.
3. To apply design optimization techniques for functional and lightweight components.
4. To understand reverse engineering, topology optimization, and quality considerations in Additive Manufacturing.
5. To prepare students for industrial design and advanced Additive Manufacturing applications.

Course Outcomes: On completion of the course, Student will be able to
CO1: EXPLAIN Design for Additive Manufacturing principles and design guidelines.
CO2: APPLY material selection and process planning techniques for Additive Manufacturing.
CO3: DEVELOP optimized designs considering topology optimization, support structure & build orientation.
CO4: EXPLAIN reverse engineering, design validation, and quality aspects of Additive Manufacturing**.**
CO5: SELECT suitable design methodologies for engineering applications using Additive Manufacturing.

Course Contents

Unit I	Introduction to Design for Additive Manufacturing	(08 Hours)

Introduction to Design for Additive Manufacturing (DfAM), Conventional Design versus DfAM, Product Development Cycle for Additive Manufacturing, Design Freedom, Functional Design, Design Constraints, Geometric Complexity, Part Consolidation, Lightweight Design, Design Rules and Guidelines, Advantages and Limitations of DfAM.

CCE Activities:
- Comparative study of conventional design and DfAM.
- Prepare design guidelines for an AM component.
- Presentation on successful DfAM industrial products.

Unit II	Material Selection and Process Planning	(08 Hours)

Materials for Additive Manufacturing, Material Properties, Material Selection Criteria, Polymer, Metal, Ceramic and Composite Materials, Selection of AM Process, Process Planning, Build Orientation, Support Structure Generation, Part Positioning, Build Time Estimation and Post-processing Considerations.

CCE Activities:
- Select suitable material for a given product.
- Assignment on build orientation.
- Comparison of different AM materials.

Unit III	Design Optimization for Additive Manufacturing	(08 Hours)

Topology Optimization, Lightweight Structures, Lattice Structures, Cellular Structures, Internal Channels, Part Consolidation, Support Structure Optimization, Design Modification for AM, Design Validation and Design Evaluation

CCE Activities:
- Case study on topology optimization.
- Prepare a lightweight redesign of an engineering component.
- Presentation on lattice structures.

Unit IV	Inkjet (Droplet)-Based Deposition and Fusion Technologies	(08 Hours)

Introduction to Reverse Engineering, 3D Scanning Techniques, CAD Reconstruction, STL Generation and Repair, Data Processing, Design Verification, Geometric Inspection, Integration of CAD and Additive Manufacturing, Introduction to Design Simulation.

CCE Activities:
- Demonstration of reverse engineering workflow.
- Assignment on STL repair.
- Report on 3D scanning applications.

Unit V	Case Studies, Applications and Special Topics	(08 Hours)

Design Case Studies in Aerospace, Automotive, Biomedical, Tooling and Consumer Products, Mass Customization, Design for Sustainability, Digital Manufacturing, Introduction to Generative Design, Industrial Design Software for Additive Manufacturing, Future Trends in Design for Additive Manufacturing.

CCE Activities:
- Literature survey on an industrial DfAM application.
- Presentation on Generative Design.
- Group discussion on future design trends in Additive Manufacturing.

Learning Resources

Text Books

1. Ali K. Kamrani, Emad Abouel Nasr, “Engineering Design and Rapid Prototyping” Springer, 2010
2. Ben Redwood, Filemon Schöffer& Brian Garret, “The 3D Printing Handbook – Technologies, Design and Applications” Part Two: Designing for 3D Printing, 3D Hubs, 2017
3. Chee Kai Chua, Chee How Wong, Wai Yee Yeong’ “Standards, Quality Control, and Measurement Sciences in 3d Printing and Additive Manufacturing” Academic Press, 2017
4. Liza Wallach Kloski and Nick Kloski, “Getting Started with 3D Printing” Part III CAD Tutorials, Maker Media, 2016

Reference Books

1. Leary Martin, "Design for Additive Manufacturing (Additive Manufacturing Materials and Technologies)" , Elsevier, 2019
2. Andreas Gebhardt, “Understanding Additive”, Hanser Publishers, Munich, 2011
3. Rupinder Singh J. Paulo Davim, “Additive Manufacturing - Applications and Innovations” CRC Press Taylor & Francis Group, 2019

4. T. S. Srivatsan, T. S. Sudarshan, “Additive Manufacturing - Innovations, Advances, and Applications” CRC Press Taylor & Francis Group, 2016
5. Steinar Killi, “Additive Manufacturing - Design, Methods and Processes”, Pan Stanford Publishing Ltd 2017
6. Larry Dosser , Kevin Hartke , Ron Jacobsen , Sarah Payne, "Additive manufacturing technology review - From prototyping to production: Additive Manufacturing Handbook", Routledge, 2017
7. Hwaiyu Geng, " Manufacturing Engineering Handbook", Second Edition, McGraw Hill, 2016
8. Bill Macy, " Reverse Engineering for Additive Manufacturing", Handbook of Manufacturing Engineering and Technology, Springer, 2014

Web References

1. NPTEL IIT Madras, “Design for Additive Manufacturing”, Prof. G. Saravana Kumar https://www.youtube.com/watch?v=gcia0aqZMf0
2. NPTEL IIT Guwahati, “Mathematical Modeling of Manufacturing Processes” Lecture 31 - Principle and development of additive manufacturing technologies-1, Prof. Swarup Bag
3. https://www.youtube.com/watch?v=7L42aRs68WI
4. NPTEL-NOC IITM, DFAM approach, “Simulation tools for AM, Design needs” mod06lec23 - Design for Additive manufacturing (DfAM) for Metal Printing, Mr. Vaman Kulkarni, Ex. Director Honeywell Technology, Bangalore; https://www.youtube.com/watch?v=I-0E-eiJdWk
5. NPTEL Course on Fundamentals of Additive Manufacturing Technologies by Prof. Sajan Kapil, IIT Guwahati, https://onlinecourses.nptel.ac.in/noc21_me115/preview

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

HADM352MEC: 3D Printing Laboratory

Teaching Scheme		Credit	Examination Scheme	
Theory	NA	1	ESE	NA
Practical	2 Hours/Week		TW	50 Marks

- **Prerequisites:** Engineering Graphics, Solid Modelling and Drafting, Engineering Materials and Metallurgy, Digital Manufacturing Laboratory, Additive Manufacturing Technology, Modelling Lab, Design for Additive Manufacturing, Additive Manufacturing System Design

Course Objectives

1. To identify the AM System Equipment Topology/Layouts, Construction and Working.
2. To select the material based AM System.
3. To understand and evaluate the AM Primary and Auxiliary System, the CAD Software and Controller Interfacing.
4. To determine the AM System Process Parameters for getting the desired performance level to build 3D parts and printer.

Course Outcomes: On completion of the course, Student will be able to

CO1. DISTINGUISH AM System Equipment Topology/Layouts, Construction and Working.

CO2. COMPARE the material based AM System.

CO3. EVALUATE the AM Primary and Auxiliary System.

CO4. DEVELOPE the AM Cell & Equipment for variety of applications.

CO5. SELECT the CAD Software and Controller Interfacing.

Guidelines for Laboratory Conduction

The student shall complete the following hands-on activities as a Term Work under the guidance of concerned faculty member. The open source software shall be preferred for conduction of practical

Term Work

The learner shall complete minimum 08 of the following activities as a Term-Work

List of Practical

The learner shall complete minimum 10 of the following activities as a Term-Work:

(Select any Four Practical from Practical # 1, 3 to 7;, Practical # 2,8,9 and 10 are Mandatory)

1. To study and Survey of existing 3D Printer/Equipment Topology and Layout (Cartesian, Polar, SCARA, Delta Articulated architecture).
2. Dis-assembly and Assembly of any two off-the shelf Do-it-yourself desktop 3D Printers Kits of different topology.
3. To study and Survey of Polymer Extrusion based FDM/FFF Additive Manufacturing System.

4. To study and Survey of Polymer/Metal based SLA/SLM/DMLS Additive Manufacturing System.
5. To study and Survey of Laser Based/ Electron Beam System and its sub-systems and Applications.
6. To study and Survey of Binder Jetting System and its sub-systems and Applications
7. Survey and Design of Heating and Cooling System required for FFF/FDM 3D Printers.
8. Survey and Design of AM Technology based Manipulation Design of Nozzle movement System and Bed Movement System.
9. Investigation of in-fill and slicing and printing strategy on final 3D Printed Product and its comparison with same CAD file using Topological Optimization Software.
10. Take any one Product containing minimum 5 parts excluding standard brought out items. Apply DfAM on that product parts using the principals of Additive Manufacturing. Start with modelling CAD file and Convert it into *.stl file. Using slicing Software convert it into G/M Code and get it 3D Printed using different types of In-fill, slicing, single and multi-printing modes. Finally assemble the product. Make Detailed Report containing concept, CAD (2D, Trimetric Drawing/Isometric and Exploded View along with Dimensions, GD&T.

List of Industrial Visits *(Select any Two Industrial Visits from Practical # 11 to 13)*

11. Industrial Visit to Any Application based Polymer 3D Printing Facility.
12. Industrial Visit to Any Application based Metal 3D Printing Facility.
13. Industrial Visit to Additive Manufacturing Machine Plant.

Instructions for Laboratory Conduction

Please note following instructions regarding Laboratory Conduction:

• The student shall complete the following hands-on activities as a Term Work under the guidance of concerned Teaching Faculty member.
• The open source software shall be preferred for conduction of practical.
• Industrial Visits to be conducted by the Teaching Faculty (subject Teacher).
• Demonstration of Topology based varieties of 3D Printers to be taught by a subject Teacher in Practical slot.

Industrial Visits

Visit to any Additive Manufacturing Machine Plant/Application based AM Printing Facility.

The visit report consists of

• Details about the Industry/Process Plant.
  • Operational description of the Equipment with specification, its use, capacity, application etc.

Learning Resources

Text Books

5. Ali K. Kamrani, Emad Abouel Nasr, "Engineering Design and Rapid Prototyping" Springer, 2010
6. Ben Redwood, Filemon Schöffer& Brian Garret, "The 3D Printing Handbook – Technologies, Design and Applications" Part Two: Designing for 3D Printing, 3D Hubs, 2017
7. Chee Kai Chua, Chee How Wong, Wai Yee Yeong' "Standards, Quality Control, and Measurement Sciences in 3d Printing and Additive Manufacturing" Academic Press, 2017
1. Liza Wallach Kloski and Nick Kloski, "Getting Started with 3D Printing" Part III CAD Tutorials, Maker Media, 2016

Reference Books

9. Leary Martin, "Design for Additive Manufacturing (Additive Manufacturing Materials and Technologies)" , Elsevier, 2019
10. Andreas Gebhardt, “Understanding Additive”, Hanser Publishers, Munich, 2011
11. Rupinder Singh J. Paulo Davim, “Additive Manufacturing - Applications and Innovations” CRC Press Taylor & Francis Group, 2019
12. T. S. Srivatsan, T. S. Sudarshan, “Additive Manufacturing - Innovations, Advances, and Applications” CRC Press Taylor & Francis Group, 2016
13. Steinar Killi, “Additive Manufacturing - Design, Methods and Processes”, Pan Stanford Publishing Ltd 2017
14. Larry Dosser , Kevin Hartke , Ron Jacobsen , Sarah Payne, "Additive manufacturing technology review - From prototyping to production: Additive Manufacturing Handbook", Routledge, 2017
15. Hwaiyu Geng, " Manufacturing Engineering Handbook", Second Edition, McGraw Hill, 2016
1. Bill Macy, " Reverse Engineering for Additive Manufacturing", Handbook of Manufacturing Engineering and Technology, Springer, 2014

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1. NPTEL IIT Madras, “Design for Additive Manufacturing”, Prof. G. Saravana Kumar https://www.youtube.com/watch?v=gcia0aqZMf0
2. NPTEL IIT Guwahati, “Mathematical Modeling of Manufacturing Processes” Lecture 31 - Principle and development of additive manufacturing technologies-1, Prof. Swarup Bag
3. https://www.youtube.com/watch?v=7L42aRs68WI
4. NPTEL-NOC IITM, DFAM approach, “Simulation tools for AM, Design needs” mod06lec23 - Design for Additive manufacturing (DfAM) for Metal Printing, Mr. Vaman Kulkarni, Ex. Director Honeywell Technology, Bangalore; https://www.youtube.com/watch?v=I-0E-eiJdWk
5. NPTEL Course on Fundamentals of Additive Manufacturing Technologies by Prof. Sajan Kapil, IIT Guwahati, https://onlinecourses.nptel.ac.in/noc21_me115/preview

Savitribai Phule Pune University, Pune

Maharashtra, India

BE - Mechanical Engineering (2024 Pattern)

SEMESTER- VII

Honor Courses

[Additive Manufacturing]

Savitribai Phule Pune University
Final Year of Mechanical Engineering (2024 Pattern)

HADM401MEC: Additive Manufacturing System Design

Teaching Scheme		Credit	Examination Scheme	
Theory	3 Hours/Week	3	CCE	30 Marks
Practical	NA		End-Semester	70 Marks

- **Prerequisites:** Basic knowledge of Additive Manufacturing Technology, Design for Additive Manufacturing, CAD/CAM, manufacturing processes, and engineering metrology

Course Objectives:

After completing this course, students will be able to:

6. To understand the architecture and components of industrial additive manufacturing systems.
7. To analyze digital workflow and production planning strategies for AM systems.
8. To understand automation, monitoring, and control systems used in AM.
9. To study quality assurance and reliability aspects of AM production systems.
1. To develop knowledge of industrial implementation and management of AM systems.

Course Outcomes: On completion of the course, Student will be able to

CO1: UNDERSTAND and Explain the architecture, components and digital workflow of industrial additive manufacturing systems.

CO2: APPLY production planning, build optimization and cost analysis techniques for efficient additive manufacturing operations.

CO3: ANALYZE process monitoring, automation and control strategies used for improving the performance of additive manufacturing systems.

CO4: EVALUATE quality assurance methods, inspection techniques, reliability aspects and industrial standards for additive manufacturing systems.

CO5: ANALYZE Design, and propose smart, sustainable and Industry 4.0-enabled additive manufacturing systems for industrial applications.

Course Contents

Unit I	Additive Manufacturing System Architecture and Digital Workflow	(08 Hours)

Additive manufacturing system architecture: components of industrial additive manufacturing systems, hardware and software architecture of AM machines, build chamber, motion systems, energy delivery systems, material handling systems, thermal management systems, control architecture of AM machines,

Digital manufacturing workflow: digital thread in additive manufacturing, CAD model preparation to final product workflow, additive manufacturing file formats including STL, AMF, 3MF and STEP, data preparation and build file generation, slicing strategies, build preparation software, simulation software, process planning software and manufacturing execution systems for additive manufacturing.

CCE Activities:

Study the architecture of a commercial AM machine (FDM/SLM/SLA/DED) and prepare a report explaining machine components, digital workflow, and software used from CAD model to printed part.

Unit II	**Additive Manufacturing Production Planning and System Optimization**	**(08 Hours)**
Production planning in additive manufacturing: part orientation selection, build volume utilization, nesting strategies, build time estimation, production scheduling, machine utilization, cost estimation models, material utilization efficiency, batch production planning, make-or-buy decisions, productivity improvement, throughput enhancement, multi-part production strategies, hybrid manufacturing systems and optimization techniques for industrial additive manufacturing.		
CCE Activities: Select an industrial component and prepare a complete production plan including part orientation, nesting, build time estimation, material utilization, machine selection, and cost analysis using slicing software.		
Unit III	**Process Monitoring, Automation and Control Systems in Additive Manufacturing**	**(08 Hours)**
Process Monitoring: need for process monitoring in industrial additive manufacturing, in-situ monitoring techniques, optical monitoring, thermal monitoring, melt pool monitoring, layer-wise inspection, **Automation and Control Systems:** automated powder handling systems, robotic additive manufacturing, automated post-processing systems, material handling automation, sensors and data acquisition systems, feedback control, adaptive process control, closed-loop control systems and artificial intelligence-based process monitoring		
CCE Activities: Study monitoring technologies used in industrial AM systems and prepare a report or presentation on optical monitoring, melt pool monitoring, automation, sensors, AI-based monitoring, or robotic AM systems.		
Unit IV	**Quality Assurance and Reliability of Additive Manufacturing Systems**	**(08 Hours)**
Quality Assurance: Quality management in additive manufacturing, quality challenges in industrial production, defect identification and prevention, process qualification and validation, in-process inspection, non-destructive testing methods, ASTM and ISO standards for additive manufacturing, aerospace and medical certification requirements, machine reliability, maintenance strategies and failure analysis of additive manufacturing systems.		
CCE Activities: Inspect 3D printed components using dimensional measurement, visual inspection, optical scanner, CMM, or image analysis. Identify manufacturing defects and suggest corrective actions based on quality standards.		
Unit V	**Smart Additive Manufacturing and Industrial Implementation**	**(08 Hours)**
Smart Additive Manufacturing: industry 4.0 integration with additive manufacturing, smart additive manufacturing factory concept, IoT-enabled additive manufacturing machines, cloud-based additive manufacturing, digital twins for additive manufacturing systems, sustainable additive manufacturing, energy consumption analysis, material recycling and reuse, sustainable production strategies, additive manufacturing adoption roadmap, infrastructure requirements, production facility planning and industrial case studies in aerospace, automotive and medical sectors.		
CCE Activities: Develop a proposal for implementing an AM production facility for a selected product, including workflow, infrastructure, Industry 4.0 integration, sustainability considerations, quality plan, and economic feasibility.		

Learning Resources

Text Books

1. Gibson, I., Rosen, D. W. and Stucker, B., Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, 3rd Edition, Springer, 2021.
2. Gebhardt, A. and Hötter, J. S., Additive Manufacturing: 3D Printing for Prototyping and Manufacturing, Hanser Publications, 2016.
3. Thompson, M. K., Moroni, G., Vaneker, T., Fadel, G., Campbell, R. I., Gibson, I., Bernard, A., Schulz, J., Graf, P., Ahuja, B. and Martina, F., Design for Additive Manufacturing: Trends, Opportunities, Considerations and Constraints, CIRP Annals (Reference Text).
4. Chua, C. K. and Leong, K. F., 3D Printing and Additive Manufacturing: Principles and Applications, 5th Edition, World Scientific Publishing, 2022.
5. Ngo, T. D., Additive Manufacturing: Principles, Technologies and Applications, CRC Press, 2021.

Reference Books

1. Kumar, L. J. and Pandey, P. M. (Eds.), Advances in 3D Printing and Additive Manufacturing Technologies, Springer, 2019.
2. ASTM International, ASTM Additive Manufacturing Standards, Latest Edition.
3. ISO/ASTM 52900 Series, Additive Manufacturing – General Principles – Terminology and Standards, Latest Edition.
4. Hilton, P. D. and Jacobs, P. F., Rapid Tooling: Technologies and Industrial Applications, CRC Press.
5. Liou, F., Rapid Prototyping and Engineering Applications: A Toolbox for Prototype Development, CRC Press.
6. Leach, R., Fundamental Principles of Engineering Nanometrology, Elsevier (for precision inspection and measurement concepts).

Web References

1. ASTM International – Additive Manufacturing Standards
2. https://www.astm.org
3. ISO – Additive Manufacturing Standards (ISO/ASTM 52900 Series)
4. https://www.iso.org
5. America Makes – National Additive Manufacturing Innovation Institute
6. https://www.americamakes.us
7. National Institute of Standards and Technology (NIST) – Additive Manufacturing Program
8. https://www.nist.gov
9. Additive Manufacturing Media
10. https://www.additivemanufacturing.media
11. Materialise – Additive Manufacturing Solutions
12. https://www.materialise.com
13. Autodesk Netfabb Learning Resources
14. https://www.autodesk.com/products/netfabb
15. Ultimaker Academy and Cura Learning Resources
16. https://ultimaker.com
17. EOS GmbH – Industrial Metal Additive Manufacturing
18. https://www.eos.info
19. SLM Solutions Group – Metal Additive Manufacturing Systems
20. https://www.slm-solutions.com

Savitribai Phule Pune University
FinalYear of Mechanical Engineering (2024 Pattern)

HADM402MEC: Seminar

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**2**	**OR**	**NA**
Practical	**2 Hours/Week**		**TW**	**50 Marks**

- **Prerequisites:** Basic knowledge of Additive Manufacturing Technology, Design for Additive Manufacturing, Additive Manufacturing System Design, engineering communication, technical report writing, literature survey, CAD/CAM, and scientific presentation skills

Course Objectives:

After completing this course, students will be able to:

1. To develop the ability to identify and study contemporary topics in additive manufacturing through literature survey.
2. To enhance technical writing, presentation and communication skills.
3. To develop analytical thinking through critical review of research papers, industrial case studies and emerging technologies.
4. To familiarize students with current industrial practices, standards and future trends in additive manufacturing.
5. To prepare students for research, higher studies and industry-oriented project work.

Course Outcomes: On completion of the course, Student will be able to

CO1: IDENTIFY and study emerging topics and recent developments in additive manufacturing.

CO2: ANALYZE research papers, patents and industrial case studies to understand current technological advancements.

CO3: **PREPARE** technical reports using appropriate scientific writing and referencing practices.

CO4: DELIVER effective technical presentations and defend their ideas through discussions.

CO5: DEMONSTRATE professional ethics, independent learning and research aptitude**.**

Course Contents

The evaluation of the Seminar shall be carried out in the following stages.

Stage-I: Topic Identification and Literature Survey

In this stage, the student is expected to complete the following:

- Selection of a seminar topic related to recent developments in Additive Manufacturing.
- Identification of the problem domain and industrial relevance.
- Literature survey using research papers, patents, technical reports, standards and conference proceedings.
- State-of-the-art review and identification of current technologies, research trends and challenges.
- Submission of synopsis and seminar plan.

Stage-II: Technical Analysis and Seminar Development

In this stage, the student is expected to complete the following:

- Problem statement and motivation.
- Objectives and scope of the seminar.
- Technical analysis of the selected topic.
- Comparative study of existing technologies, methodologies or industrial practices.
- Review of recent research contributions and future research opportunities.

Stage-III: Critical Evaluation and Report Preparation

In this stage, the student is expected to complete the following:

- Analysis and interpretation of technical information collected from literature.
- Discussion of industrial applications, advantages, limitations and future scope.
- Conclusions and recommendations.

Preparation of the draft seminar report.

Stage-IV: Final Seminar Presentation

In this stage, the student is expected to complete the following:

- Submission of the final seminar report prepared according to the prescribed format.
- Oral presentation using appropriate audio-visual aids.
- Demonstration (if applicable) of software, simulation or prototype.
- Question-answer session and viva voce.

Learning Resources

Text Books

1. Gibson, I., Rosen, D. W. and Stucker, B., Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, 3rd Edition, Springer Nature, Switzerland, 2021.
2. Chua, C. K. and Leong, K. F., 3D Printing and Additive Manufacturing: Principles and Applications, 5th Edition, World Scientific Publishing, Singapore, 2022.
3. Gebhardt, A. and Hötter, J. S., Additive Manufacturing: 3D Printing for Prototyping and Manufacturing, Hanser Publications, Germany, 2016.
4. Ngo, T. D., Additive Manufacturing: Principles, Technologies and Applications, CRC Press, Taylor & Francis Group, USA, 2021.
5. Kumar, L. J. and Pandey, P. M. (Eds.), Advances in 3D Printing and Additive Manufacturing Technologies, Springer, Singapore, 2019.

Reference Books

1. Kumar, L. J. and Pandey, P. M. (Eds.), Advances in 3D Printing and Additive Manufacturing Technologies, Springer, 2019.
2. ASTM International, ASTM Additive Manufacturing Standards, Latest Edition.
3. ISO/ASTM 52900 Series, Additive Manufacturing – General Principles – Terminology and Standards, Latest Edition.
4. Hilton, P. D. and Jacobs, P. F., Rapid Tooling: Technologies and Industrial Applications, CRC Press.
5. Liou, F., Rapid Prototyping and Engineering Applications: A Toolbox for Prototype Development, CRC Press.

   Leach, R., Fundamental Principles of Engineering Nanometrology, Elsevier (for precision inspection and measurement concepts).

Papers from Journals or Transactions
1. Gibson, I., Rosen, D. W. and Stucker, B., "Additive Manufacturing Technologies: State of the Art, Challenges and Future Directions," *Additive Manufacturing*, Elsevier, Vol. 21, 2018, pp. 758–774. 2. Ngo, T. D., Kashani, A., Imbalzano, G., Nguyen, K. T. Q. and Hui, D., "Additive Manufacturing (3D Printing): A Review of Materials, Methods, Applications and Challenges," *Composites Part B: Engineering*, Vol. 143, 2018, pp. 172–196. 3. DebRoy, T., Wei, H. L., Zuback, J. S., et al., "Additive Manufacturing of Metallic Components – Process, Structure and Properties," *Progress in Materials Science*, Vol. 92, 2018, pp. 112–224. • Herzog, D., Seyda, V., Wycisk, E. and Emmelmann, C., "Additive Manufacturing of Metals," *Acta Materialia*, Vol. 117, 2016, pp. 371–392
Papers from Conference Proceedings
1. Shamsaei, N., Seifi, M. and Hrabe, N. (Eds.), *Proceedings of the ASTM International Conference on Additive Manufacturing (ICAM)*, ASTM International, USA 2. Wohlers Associates, *Proceedings of Additive Manufacturing Conferences and Industrial Forums*, Wohlers Associates, USA. 3. Proceedings of the *International Solid Freeform Fabrication (SFF) Symposium*, The University of Texas at Austin, USA.
Patents
• United States Patent and Trademark Office (USPTO). • European Patent Office (EPO). • World Intellectual Property Organization (WIPO – PATENTSCOPE). • Indian Patent Advanced Search System (InPASS).
Web References
• ASTM International – https://www.astm.org • ISO – https://www.iso.org • America Makes – https://www.americamakes.us • National Institute of Standards and Technology (NIST) – https://www.nist.gov • Additive Manufacturing Journal (Elsevier) – https://www.sciencedirect.com/journal/additive-manufacturing • Materialise – https://www.materialise.com • Autodesk Netfabb – https://www.autodesk.com/products/netfabb

Savitribai Phule Pune University, Pune

Maharashtra, India

BE - Mechanical Engineering (2024 Pattern)

SEMESTER- VIII

Honor Courses

[Additive Manufacturing]

Savitribai Phule Pune University
Final Year of Mechanical Engineering (2024 Pattern)

HADM451MEC: 3D Printing Applications & Entrepreneurship

Teaching Scheme		Credit	Examination Scheme	
Theory	3 Hours/Week	3	CCE	30 Marks
Practical	NA		End-Semester	70 Marks

- **Prerequisites:** Basic knowledge of Additive Manufacturing Technology, Design for Additive Manufacturing, Additive Manufacturing System Design, CAD/CAM, manufacturing processes, product development, and quality management

Course Objectives:

After completing this course, students will be able to:

1. To understand the applications of 3D printing in aerospace, automotive, healthcare, construction, consumer products and other industrial sectors.
2. To develop knowledge of product development, commercialization and business opportunities using additive manufacturing.
3. To understand business models, cost analysis, market assessment and startup planning for additive manufacturing enterprises.
4. To study intellectual property rights, standards, certification and regulatory requirements for additive manufacturing products.
5. To develop entrepreneurial skills for planning, designing and launching innovative additive manufacturing-based products and businesses.

Course Outcomes: On completion of the course, Student will be able to

CO1: EXPLAIN the applications of 3D printing in aerospace, automotive, healthcare, construction and consumer product industries.

CO2: ANALYZE advanced and emerging applications of additive manufacturing for solving industrial and societal challenges.

CO3: DEVELOP business models, market strategies and economic feasibility studies for additive manufacturing-based enterprises.

CO4: APPLY product development methodologies, commercialization strategies, intellectual property rights and regulatory requirements for additive manufacturing products.

CO5: DESIGN an innovative additive manufacturing-based product and prepare a complete entrepreneurial plan for its commercialization.

Course Contents

Unit I	Industrial Applications of 3D Printing	(08 Hours)

Introduction to industrial applications of 3D printing, industrial adoption of additive manufacturing, advantages and limitations of additive manufacturing, applications in aerospace including lightweight structures, engine components and satellite parts, automotive applications including rapid prototyping, tooling, customized components and lightweight structures, medical applications including patient-specific implants, prosthetics, surgical guides and anatomical models, applications in tooling, education, consumer products and manufacturing industries

CCE Activities:

Study an industrial application of 3D printing in aerospace, automotive, healthcare or consumer products and prepare a technical report highlighting process selection, advantages and limitations.

Unit II	Advanced Applications of Additive Manufacturing	(08 Hours)

Biomedical and healthcare applications including bioprinting, tissue engineering, dental restorations and medical devices, architecture and construction applications including 3D printed buildings and construction automation, consumer and lifestyle products including jewellery, fashion, customized consumer goods and sports equipment, food printing, printed electronics, sensors, smart devices, defence applications including lightweight components, spare parts and field manufacturing, emerging applications in energy, marine and space industries.

CCE Activities:

Prepare a seminar or poster on advanced applications such as bio printing, construction printing, food printing, printed electronics or defense applications.

Unit III	Additive Manufacturing Business Models	(08 Hours)

Entrepreneurship opportunities in additive manufacturing, additive manufacturing service bureaus, rapid prototyping services, customized manufacturing, product development companies, business models including on-demand manufacturing, distributed manufacturing, digital inventory and online 3D printing platforms, startup planning, market analysis, customer identification, value proposition, business model canvas, cost estimation, pricing strategies, return on investment (ROI) analysis and funding opportunities for additive manufacturing startups.

CCE Activities:

Develop a Business Model Canvas (BMC) for a 3D printing startup including customer segments, value proposition, revenue streams, cost structure and marketing strategy.

Unit IV	Product Development and Commercialization Using 3D Printing	(08 Hours)

Product development process including idea generation, concept development, CAD modelling, prototyping, testing and validation, design optimization for customer requirements, functional prototyping, product customization, quality assurance, standards and certification requirements, regulatory aspects for industrial and medical products, intellectual property rights including patents, copyrights, trademarks, design registration and protection of digital design files, commercialization strategies and product launch planning.

CCE Activities:

Develop a prototype or product concept using 3D printing and prepare documentation covering design process, testing, certification requirements and intellectual property considerations.

Unit V	Future Trends and Entrepreneurial Project in 3D Printing	(08 Hours)

Future trends in additive manufacturing including artificial intelligence, machine learning, digital twins, cloud manufacturing, Industry 4.0 integration, sustainable manufacturing, circular economy, material recycling, 4D printing and smart materials, industrial case studies in aerospace, automotive, healthcare and consumer products, entrepreneurial project involving product idea generation, market survey, business model development, prototype fabrication, cost estimation, marketing strategy and business presentation

CCE Activities:

Prepare a complete start up proposal including product idea, market survey, prototype, business plan, cost estimation, funding requirements and commercialization strategy.

Learning Resources

Text Books

1. Gibson, I., Rosen, D. W. and Stucker, B., Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, 3rd Edition, Springer, 2021.
2. Chua, C. K. and Leong, K. F., 3D Printing and Additive Manufacturing: Principles and Applications, 5th Edition, World Scientific Publishing, 2022.
3. Gebhardt, A. and Hötter, J. S., Additive Manufacturing: 3D Printing for Prototyping and Manufacturing, Hanser Publications, 2016.
4. Ngo, T. D., Additive Manufacturing: Principles, Technologies and Applications, CRC Press, 2021.
5. Ries, E., The Lean Startup, Crown Business, 2011.

Reference Books

1. Kumar, L. J. and Pandey, P. M. (Eds.), Advances in 3D Printing and Additive Manufacturing Technologies, Springer, 2019.
2. Blank, S. and Dorf, B., The Startup Owner's Manual, K&S Ranch.
3. Osterwalder, A. and Pigneur, Y., Business Model Generation, Wiley.
4. ASTM International, ASTM Additive Manufacturing Standards, Latest Edition.
5. ISO/ASTM 52900 Series, Additive Manufacturing – General Principles – Terminology, Latest Edition.
6. Rogers, E. M., Diffusion of Innovations, 5th Edition, Free Press.

Web References

1. ASTM International – https://www.astm.org
2. ISO – https://www.iso.org
3. America Makes – https://www.americamakes.us
4. National Institute of Standards and Technology (NIST) – https://www.nist.gov
5. Additive Manufacturing Media – https://www.additivemanufacturing.media
6. Materialise – https://www.materialise.com
7. Autodesk Netfabb – https://www.autodesk.com/products/netfabb
8. Ultimaker – https://ultimaker.com
9. EOS GmbH – https://www.eos.info
10. Stratasys – https://www.stratasys.com

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Savitribai Phule Pune University
Final Year of Mechanical Engineering (2024 Pattern)

HADM452MEC: : Industry Oriented 3D Printing Project

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**2**	**OR**	**NA**
Practical	**2 Hours/Week**		**TW**	**50 Marks**

- **Prerequisites** Knowledge of Additive Manufacturing Technology, Design for Additive Manufacturing, Additive Manufacturing System Design, 3D Printing Applications & Entrepreneurship, CAD/CAM, slicing software, manufacturing processes, product development, quality control, engineering economics and project management.

Course Objectives:

After completing this course, students will be able to:

1. To apply additive manufacturing principles for solving real industrial problems.
2. To develop skills in product design, prototype development, testing and validation using 3D printing technologies.
3. To provide exposure to industrial practices, standards and professional engineering documentation.
4. To encourage innovation, teamwork and interdisciplinary problem solving through industry-oriented projects.
5. To develop entrepreneurial and project management skills for commercialization of additive manufacturing products.

Course Outcomes: On completion of the course, Student will be able to

CO1: IDENTIFY and **FORMULATE** industrial problems that can be addressed using additive manufacturing technologies.

CO2: DESIGN and **DEVELOP** functional products by applying Design for Additive Manufacturing principles and appropriate manufacturing processes.

CO3: Fabricate, test and **VALIDATE** prototypes using suitable additive manufacturing technologies and quality evaluation techniques.

CO4: EVALUATE technical, economic, environmental and sustainability aspects of additive manufacturing-based industrial solutions.

CO5: DEMONSTRATE professional ethics, teamwork, project management, technical communication and entrepreneurial skills through successful completion of an industry-oriented project.

Course Contents

The evaluation of the Industry Oriented 3D Printing Project is proposed through the following stages

Stage-I: Problem Identification and Project Planning

In this stage, the student (or student group) is expected to complete the following:

- Identification of an industry-oriented problem related to additive manufacturing.
- Interaction with industry, start-up, research laboratory or faculty mentor.
- Literature survey, patent search and study of existing industrial practices.
- Definition of problem statement, objectives and scope of work.
- Preparation of project synopsis and project execution plan.

Stage-II: Design and Development

In this stage, the student is expected to complete the following:

- Concept generation and selection.
- CAD modelling and Design for Additive Manufacturing (DfAM).
- Material selection and process selection.
- Build preparation, slicing and manufacturing planning.
- Cost estimation and feasibility analysis.

Stage-III: Prototype Fabrication and Validation

In this stage, the student is expected to complete the following:

- Prototype fabrication using suitable additive manufacturing technology.
- Post-processing and finishing operations.
- Testing, inspection and quality evaluation.
- Performance analysis and validation of results.
- Discussion on technical, economic and sustainability aspects of the developed product.

Stage-IV: Project Completion and Evaluation

In this stage, the student is expected to complete the following:

- Submission of the final project report in the prescribed format.
- Demonstration of the developed prototype or industrial solution.
- Project presentation before the evaluation committee.
- Viva voce and discussion on technical and industrial aspects of the project.

Term Work

1. The student shall prepare the duly certified final report of project work in standard format for satisfactory completion of the work by the concerned guide and head of the Department/Institute.
2. Recommended performance measure parameters may Include-Problem definition and scope.
3. of the project, Literature Survey, Appropriate Engineering approach used, Exhaustive and Rational Requirement Analysis,
4. Comprehensive Implementation - Design, modeling, documentation, Usability, Optimization considerations (Time, Resources, Costing), Thorough Testing, Project Presentation and Demonstration (ease of use and usability), Social and environment aspects.
5. The term work under project submitted by students shall include 1. Work Diary: Work Diary maintained by group and countersigned by the guide weekly. The contents of work diary shall reflect the efforts taken by project group for a. Searching suitable project work b. Brief report preferably on journals/ research or conference papers/ books or literature surveyed to select and bring up the project. c. Brief report of feasibility studies carried to implement the conclusion. d. Rough Sketches/ Design Calculations e. Synopsis
6. The group should submit the synopsis in the following form. i. Title of Project ii. Names of Students iii. Name of Guide iv. Relevance v. Present Theory and Practices vi. Proposed work vii. Expenditure viii. References
7. The synopsis shall be signed by each student in the group, approved by the guide (along with external guide in case of sponsored projects) and endorsed by the Head of the Department
8. Presentation: The group has to make a presentation in front of the faculty of department at the end of semester.

Examination Scheme:

During university examination Internal examiner (preferably the guide) and External examiners jointly, evaluate the project work.

Component	Marks
TERM WORK	
Problem Identification & Planning	05
Literature Survey	05
Data Collection & Analysis	10
Design/Development of Solution	10
Implementation & Validation	10
Project Report	10
ORAL	
Presentation & Viva-Voce	50
Total	**100**

Reference Books

10. Kumar, L. J. and Pandey, P. M. (Eds.), Advances in 3D Printing and Additive Manufacturing Technologies, Springer, 2019.
11. ASTM International, ASTM Additive Manufacturing Standards, Latest Edition.
12. ISO/ASTM 52900 Series, Additive Manufacturing – General Principles – Terminology and Standards, Latest Edition.
13. Hilton, P. D. and Jacobs, P. F., Rapid Tooling: Technologies and Industrial Applications, CRC Press.
14. Liou, F., Rapid Prototyping and Engineering Applications: A Toolbox for Prototype Development, CRC Press.
1. Leach, R., Fundamental Principles of Engineering Nanometrology, Elsevier (for precision inspection and measurement concepts).

Web References

1. ASTM International – https://www.astm.org
2. ISO – https://www.iso.org
3. America Makes – https://www.americamakes.us
4. National Institute of Standards and Technology (NIST) – https://www.nist.gov
5. Additive Manufacturing Journal (Elsevier) – https://www.sciencedirect.com/journal/additive-manufacturing
6. Materialise – https://www.materialise.com
7. Autodesk Netfabb – https://www.autodesk.com/products/netfabb
8. EOS GmbH – https://www.eos.info
9. Stratasys – https://www.stratasys.com

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