Scheme for B.Tech. Mechanical Engineering with Honors in Advanced Manufacturing Technologies

Department of Mechanical Engineering

S. No	Course Code	Course Title	Sem.	L	T	P	Credits	No of Hrs	Total Credit
		Advanced Manufacturing Technologies$							
1		Metal Additive Manufacturing	V	3	0	0	3	3	
2		AM, PM&M, Mfg. Automation Lab	V	0	0	6	3	6	
3		Precision Manufacturing and Measurement	VI	3	0	0	3	3	
4		Manufacturing Automation	VI	3	0	0	3	3	
5		Micro-Nano Fabrication	VII	2	1	0	3	3	
6		Mini Project on AMTs	VIII	0	0	6	3	6	18

DUGC Convenor

Head, ME

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06/05/24

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DETAILS OF THE COURSE: Honors: Advanced Manufacturing Technologies

Course Code	Course Title	Credits	Lecture	Tutorial	Practical
	Metal Additive Manufacturing	3	3	0	0

PREREQUISITE : Manufacturing Technology

COURSE OUTCOMES:

CO1	To learn what Additive manufacturing (AM) is and understand why it has become one of the most important technology trends in decades for product development and innovation
CO2	To learn metal based design and fabrication processes.
CO3	To understand the latest trends and business opportunities in metal AM, distributed manufacturing and mass customization.
CO4	To solve additive manufacturing problems for industrial components.

COURSE CONTENTS

Introduction to the Principles of Metal Additive Manufacturing: Overview of Metal Additive Manufacturing Processes and Technology, Metal AM Process Workflow, A Closer Look at commercial Machines, Preparing Files for metal 3D Printing, Choosing the Right Materials.

Advancements in Powder Metallurgy: Effect of *Powder characteristics on product performance including in additive techniques. HIP & Mechanism of sintering, driving force for pore shirking, solid and liquid phase sintering - Impregnation and Infiltration. Applications and advancements in PM based technologies.*

Software & Methods: Design/Fabrication Processes: Designing for Additive Manufacturing (DfAM), Data Sources, Software Tools, AM File Formats,

Generative Design: Generative design mindset- Shape optimization vs generative design. Generative design preserve and obstacle geometry: Preserve geometry - Create obstacle geometry for motor mounts -Create obstacle geometry for the gas tank and motor. Model Pre- & Post-processing 3D Scanning & the Scanning Process, Sculpting & Repairing data

Metal AM Technologies: Evolution from Powder Metallurgy, Beam Deposition, Sheet Lamination, Direct-Write, Powder Bed Fusion, and the latest new methods for printing metal parts

Applications of Metal AM: Direct Digital Manufacturing, Distributed Manufacturing, Mass Customization, Health care and Biomedical Applications, Aerospace & Automotive Applications, Personalized Surgery equipment and other Applications

The Business of AM: Intellectual Property, Product Development, Commercialization, Trends, Business Opportunities and Future Directions in Metal Additive Manufacturing, Industry case studies from industrial experts.

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher & Year): -

1. Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, 2nd Ed. (2015), Ian Gibson, David W. Rosen, Brent Stucker.
2. Additive Manufacturing, Second Edition, Amit Bandyopadhyay Susmita Bose, CRC Press Taylor & Francis Group, 2020.
3. Additive Manufacturing: Principles, Technologies and Applications, C.P Paul, A.N Junoop, McGrawHill, 2021.

ONLINE/E RESOURCES

1. https://www.harlalsinghmali.in/
2. https://courses.gen3d.com/courses/enrolled/988400
3. https://courses.gen3d.com/courses/enrolled/988400
4. https://www.rapidmade.com/design-for-additive-manufacturing
5. Motivation for Additive Manufacturing: Perspectives on the Future of Design *https://youtu.be/8gtJJixzziU*

UG SCHEME 2022: Department of Mechanical Engineering

Malaviya National Institute of Technology Jaipur

DETAILS OF THE COURSE: Honours: Advanced Manufacturing Technologies

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
	AM, PM&M, Mfg. Automation Lab	3	0	0	6	0

PREREQUISITE : Product Realization through Manufacturing

COURSE OUTCOMES:

CO1	Gain practical experience in operating and troubleshooting metal additive manufacturing equipment.
CO2	Design, optimize, and 3D print parts using different materials and processes.
CO3	Apply CAD/CAM software to design, simulate, and generate tool paths for Precise CNC milling machines and CNC trainers.
CO4	Analyze the effect of process parameters on part quality, accuracy, and performance through experimental studies on precise micro machines.
CO5	Gain practical experience in manufacturing automation through programming equipment like PLCs.
CO6	Gain practical experience in manufacturing automation through programming equipment like Industrial Robots.

COURSE CONTENTS

S. N	Name of Experiments
	Metal Additive Manufacturing
1	Effect of layer thickness on part strength: Design and print specimens with varying layer thicknesses and perform mechanical tests (e.g., tensile, compressive) to investigate the effect of layer thickness on part strength. Comparison of different infill patterns: Design and print test specimens with different infill patterns (e.g., honeycomb, rectilinear) and perform mechanical tests to compare their mechanical properties (e.g., strength, stiffness).
2	Effect of print orientation on part strength: Design and print test specimens with different print orientations (e.g., flat, vertical) and perform mechanical tests to investigate the effect of print orientation on part strength. Optimization of print parameters: Design and print specimens with varying print parameters (e.g., print speed, temperature) to optimize the printing process for a specific material and part geometry.
3	Dimensional accuracy of printed parts: Design and print test specimens with different geometries (e.g., cubes, cylinders) and perform dimensional analysis to investigate the accuracy of the printing process. Warping and distortion analysis: Design and print test specimens with different geometries and evaluate the degree of warping and distortion that occurs during the printing process. Biocompatibility analysis: Design and print test specimens with different biocompatible materials and perform a biocompatibility experiment to investigate the suitability of the material for medical applications
	Precision Manufacturing & Measurement
4	Cutting speed and feed rate optimization: Identify the optimal cutting speed and feed rate for a given material and tool using different micro tool geometries. Tool life analysis in micro fabrication: Analyze the tool life for different materials and cutting conditions by measuring the tool wear and comparing the results. Surface roughness analysis: Investigate the effect of cutting speed, feed rate, and tool geometry on surface roughness by measuring the surface roughness of test specimens using a surface profilometer. Tolerance analysis in micro machines: Analyze the dimensional accuracy of parts by measuring the dimensions of test specimens using precision measuring tools (e.g., micrometer, caliper, CMM). Material removal rate analysis in micro machines: Measure the material removal rate for different cutting conditions to evaluate the productivity of the machining process
5	Micro-machining CNC programming: Develop and optimize CNC programs for specific parts using different programming techniques (e.g., G-code, CAM software).
	Manufacturing Automation
6	Speed Control circuits for double acting cylinder (Automation), A synchronization circuit for two cylinders, Continuous reciprocation of the double acting cylinder, Sequencing of two-cylinder circuits, Cascading circuit for trapped signals-2 groups
7	Programming PLC through Logic Circuits AND / OR
8	Basic Electro Pneumatic Circuits: Continuous reciprocation of cylinder (with timer and counter) Sequencing of two cylinders,
9	Force, Velocity calculations in Hydraulic Linear actuation, Speed Control of AC Servo Motor using open and closed loop control, Run A Stepper Motor: For Required Angle, Experimentation on PLC Application Trainer, PLC Control Pneumatic/ Hydraulic linear actuator circuitst, Water Level Controller using PLC, PLC Controlled Material Handling System, Process Control using Virtual Instrumentation.
10	Force, Velocity calculations in Hydraulic Linear actuation, Speed Control of AC Servo Motor using open and closed loop control, Run A Stepper Motor: For Required Angle, Experimentation on PLC Application Trainer, PLC Control Pneumatic/ Hydraulic linear actuator circuits, Water Level Controller using PLC, PLC Controlled Material Handling System, Process Control using Virtual Instrumentation.
11	Pick and place operation of Robot in Manual Mode, PLC Controlled Material Handling System, Process Control using Virtual Instrumentation, Characteristics of Inductive, capacitive and photoelectric proximity sensors, Operating a simple load using relays, switches and pushbuttons using PLC.

TEXT BOOKS/ REFERENCE BOOKS:-

1. CNC Programming Handbook, by Peter Smid.
2. Mastering 3D Printing, by Joan Horvath and Rich Cameron.
3. Automation Studio Catalogue

DETAILS OF THE COURSE: Honors: Advanced Manufacturing Technologies

UG SCHEME 2022: Department of Mechanical Engineering

Malaviya National Institute of Technology Jaipur

Course Code	Course Title	Credits	Lecture	Tutorial	Practical
	Precision Manufacturing and Measurement	3	3	0	0

PREREQUISITE : Basic knowledge on Manufacturing Technology and measurement

COURSE OUTCOMES

CO1	To be able to explain the principles of CAD/ CAM/ CAE and their applications in manufacturing technology
CO2	Appreciate fundamentals of contact and non-contact inspection techniques along with quality control techniques for its implementation in various measurement applications
CO3	To gain an understanding of the latest trends and advancements in CAM&M.
CO4	To be able to use these skills developed to his / her projects.

COURSE CONTENTS

Concepts of precision engineering: Machine tool variables- accuracy, repeatability, stiffness, spindle vibration, flatness, straightness, and smoothness of motion, 1-2 DOF systems, feedback variables, cutting tool variables, workpiece variables, environment effects and thermal errors. Machine design for precision manufacturing, principles of measurement mechanical errors, working and accuracies of Diamond Turning Machining.

Role of CAD/CAM tools in Precision Engineering: Numerical control – Concepts computer assisted part programming; Virtual engineering components and applications.

Contact Inspection Techniques: Fundamentals, Coordinate Measuring Machine, Programming of CMM, Compensation, DMIS file components, Computer Aided Inspection Planning, Automatic Feature and GD&T extraction, Integration of CAD and Inspection Planning.

Non-contact Inspection Techniques: Introduction to Machine Vision and its applications, Image Acquisition and Digitization techniques, Image Processing and Analysis Techniques, Interpretation of the image data, Optical inspection methods – Comparators, Laser Scanners and Linear Arrays, Non-optical methods – Radiation Techniques, Ultrasonic methods. Introduction to Precision engineering and practices: definitions, sources of error.

Industry Specific lectures: Industry case studies from industrial experts.

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher & Year)

1. Mikell P. Groover. Automation, Production Systems, and Computer-Integrated Manufacturing, 4th Edition, Prentice Hall, 2013.

ONLINE/E RESOURCES

1. https://nptel.ac.in/courses/108105063
2. https://www.coursera.org/specializations/roboticprocessautomation
3. https://ocw.mit.edu/courses/2-12-introduction-to-robotics-fall-2005/pages/syllabus/

UG SCHEME 2022: Department of Mechanical Engineering

Malaviya National Institute of Technology Jaipur

DETAILS OF THE COURSE: Honours: Advanced Manufacturing Technologies

Course Code	Course Title	Credits	Lecture	Tutorial	Practical
	Manufacturing Automation	3	3	0	0

PREREQUISITE : Manufacturing Technology, Digital logics and basic mechatronics

COURSE OUTCOMES:

CO1	Understand the basic concepts and principles of manufacturing automation
CO2	Design and evaluate automation and robotics systems for specific manufacturing applications.
CO3	Program and control automation and robotics systems using appropriate software and hardware tools
CO4	Identify and analyze different automation and robotics systems used in manufacturing.
CO5	Apply knowledge of automation and robotics to solve real-world manufacturing problems.

COURSE CONTENTS

Introduction: Automation in production system, Historical developments and future trends in manufacturing automation, Principles and Strategies of automation, Basic elements of an automated system, Levels of automation.

Manufacturing Process Automation:

Manufacturing Systems: Components of Manufacturing systems, Classification scheme for Manufacturing systems, single station manufacturing cells, fundamentals of manual assembly lines, automated production lines.

Material Handling: Material Handling Equipment's, Principles and Design Consideration in material handling, Material Transport Equipment, Automated Storage systems automated material handling and storage systems, Robotic assembly and disassembly processes, Industrial robotics in welding, cutting, and machining, Quality control and inspection in automated processes.

Industrial Automation Systems: Use of Sensors and actuators in automation systems, Programmable logic controllers (PLCs), Supervisory control and data acquisition (SCADA) systems, Human-machine interfaces (HMIs) and operator panels. Automated Production Lines and Assembly systems: Applications of Automated production lines, System configurations, Work Part Transfer Mechanisms, Storage Buffers, Power Transmission Systems- Gears, Power Screws (Linear Guideways), Other Transmissions Systems such as chains and ropes.

Industrial *Robotic Systems:* Robot kinematics and dynamics, Robot programming languages and software, Robot control architectures and algorithm, Robot safety standards and risk assessment. Advanced Robotics: Robot vision systems and image processing, Mobile robotics and autonomous navigation, Sensor fusion for perception and localization, Robot learning and adaptive control.

Automation System Integration: Design considerations for automation systems, Interfacing and integration of automation components, Communication networks in manufacturing automation, Cybersecurity and data integrity in automation systems.

Industrial Applications of Robotics: Collaborative robotics and human-robot collaboration, Robotic applications in assembly and packaging, Robotic automation in material handling and logistics, Emerging trends in industrial robotics and automation

Industry Specific lectures: Industry case studies from industrial experts.

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher & Year): -

1. Automation, Production Systems and Computer Integrated Manufacturing- M. P. Groover, Pearson Education. Third edition/Fifth edition, 2009.
2. Andrew Parr, Industrial drives, Butterworth – Heineamann
3. Nof, S. Y. (2018). Handbook of Automation. Springer.
4. Corke, P. (2017). Robotics, Vision and Control: Fundamental Algorithms in MATLAB. Springer.
5. M.P. Groover, E.M. Zimmers, Jr. CAD/CAM; Computer Aided Design and Manufacturing, Prentice Hall of India.
6. S. Brian Morriss. Programmable Logic Controllers, 6th Edition, Cengage Learning, 2015.
7. Miguel A. Salichs, Luis Moreno, and Oscar Lazaro. Industrial Robots Programming: Building Applications for the Factories of the Future, Springer, 2018.

ONLINE/E RESOURCES

1. https://archive.nptel.ac.in/courses/112/105/112105249/
2. https://www.edx.org/learn/robotic-process-automation
3. https://archive.nptel.ac.in/courses/112/103/112103174/
4. https://www.harlalsinghmali.in/downloads

UG SCHEME 2022: Department of Mechanical Engineering

Malaviya National Institute of Technology Jaipur

DETAILS OF THE COURSE: Honours: Advanced Manufacturing Technologies

Course Code	Course Title	Credits	Lecture	Tutorial	Practical
	Micro-Nano Fabrication	3	3	0	0

PREREQUISITE : Manufacturing Technology, Machine Tools and Digital Manufacturing

COURSE OUTCOMES:

CO1	To give understanding of the micro-machining capabilities, limitations, and productivity of advanced manufacturing processes.
CO2	To give understanding of the technologies and advancements in thermal, abrasive, electro-chemical and beam technologies for micro-nano fabrication.
CO3	To give understanding of the technologies and advancements in high strain rate forming, welding, casting and powder metallurgical technologies for micro-nano fabrication.
CO4	To give understanding of the technologies for hybrid manufacturing technologies for micro-nano fabrication.

COURSE CONTENTS

Introduction: Introduction and classification of Advanced Manufacturing Technologies, Current trends and future prospects in advanced manufacturing technologies.

Micro-Electric Discharge Machining (EDM): Attributes of process characteristics on MRR, accuracy, HAZ etc., EDM variants including Wire EDM, applications and advancements.

Micro-Electro chemical machining (ECM): Attributes of ECM process, Characteristics on MRR, accuracy, surface roughness etc., application and advancements.

Micro-Laser Beam Machining (LBM), Micro-Electron Beam Machining (EBM), Plasma arc Machining (PAM), Ion beam Machining (IBM) - Attributes of process characteristics on MRR, accuracy etc., and structure of HAZ. Applications and advancements in beam technologies.

Micro-Ultrasonic Machining (USM): Parametric effects like amplitude, frequency of vibration, grain diameter, slurry, tool material attributes and hardness of work material on performance.

Hybrid manufacturing technologies: Need for hybridization in micro-manufacturing domain and hybrid manufacturing development case studies.

Nano-finishing technologies: Abrasive Flow Machining, Magnetic Abrasive Finishing. Magnetorheological Abrasive Flow Finishing, Magnetic Float Polishing, Elastic Emission Machining. Effects of parameters, applications and advancements in abrasive technologies.

Advancements in Forming, Welding and Casting Technologies: *Micro-formed metal parts, Micro welding including green welding processes. Micro casting technologies: including role of software's in Gating Design and Mold Flow Analysis. Industry Specific lectures: Industry case studies from industrial experts.*

TEXT BOOKS/ REFERENCE BOOKS :

1. Micromanufacturing Processes (Editor: VKJain), published by CRC press, USA.
2. (Nanofinishing Science and Technology (Editor: VKJain), published by CRC press, USA.
3. ASTME, High velocity forming of metals, PHI, 1968.

ONLINE/E RESOURCES

1. https://www.harlalsinghmali.in/
2. https://archive.nptel.ac.in/courses/112/107/112107078/
3. https://nptel.ac.in/courses/112107078
4. https://www.coursera.org/learn/advanced-manufacturing-enterprise
5. https://www.edx.org/course/fundamentals-of-manufacturing-processes
6. https://www.edx.org/micromasters/mitx-principles-manufacturing

UG SCHEME 2022: Department of Mechanical Engineering

Malaviya National Institute of Technology Jaipur

DETAILS OF THE COURSE: Honors: Advanced Manufacturing Technologies

Course Code	Course Title	Credits	Lecture	Tutorial	Practical
	Mini Project on AMTs	3	0	0	6

PRE- REQUISITE

- Understands the basic principles of manufacturing technologies.
- Knows to acquire, clean, and explore data for AI.
- Knows the skills of CAD/CAM/CAE tools.

COURSE OUTCOMES

CO1	To develop understanding related to any one manufacturing system
CO2	To be able to select and plan for implementation of AI in manufacturing system.
CO3	To be able to do calculations related to AI in manufacturing.
CO4	To be able to develop PoC and present implementation of AI in manufacturing.

COURSE CONTENTS

Project on Implementation of AI techniques in any real-life manufacturing system like the cases shown below: -

- Investigate the use of digital manufacturing techniques to create Orthopaedic implants that are made specifically for each patient and are adapted to their unique anatomy.
- Design and simulation of a digitally produced prosthetic limb: Create a prosthetic limb using computer-aided design (CAD) software, and then use finite element analysis (FEA) software to simulate its performance in various scenarios.
- Examine the use of additive manufacturing methods, such 3D printing, to create lightweight, strong components for use in aircraft applications.
- Creating a digital twin of a factory: integrating Internet of Things (IoT) sensors, data analytics, and machine learning algorithms for maximising output while decreasing maintenance breaks.
- Design and implement a robotic system that can effectively automate a targeted manufacturing process, thereby enhancing both productivity and quality.
- Design and evaluation of a mass customisation digital manufacturing system: Look into the use of digital manufacturing technologies such as robotic automation and additive manufacturing to mass-produce customised products.

Additive Manufacturing for Tooling: Explore the use of additive manufacturing for the production of customized tooling solutions. Design and fabricate complex tooling structures with improved functionality and performance using additive manufacturing technologies. Validate the performance and durability of the 3D-printed tooling through testing and comparison with traditional tooling methods.

Human-Machine Collaboration for Assembly Automation: Develop a collaborative robotic system that can work alongside human operators for assembly tasks, implement advanced control algorithms to enable safe and efficient human-robot collaboration, Design intuitive interfaces and interaction mechanisms to facilitate seamless

RECOMMENDED READINGS

1. https://www.djkasiagroup.com/business/ai.html?gclid=EAIaIQobChMImp7E0uSy_gIVAT8rCh1d1QgMEAAYAiAAEgJcovD_BwE
2. https://www.simplilearn.com/growing-role-of-ai-in-manufacturing-industry-article