NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL



Honors in
SMART MANUFACTURING

SCHEME OF INSTRUCTION AND SYLLABI

for B.Tech. Program

(Effective from 2021-22)

DEPARTMENT OF MECHANICAL ENGINEERING

Scheme of Instruction
Honors in Smart Manufacturing

S.No.	Subject	Semester
1	ME5701 Design for Additive Manufacturing	Odd
2	ME5702 Additive Manufacturing Processes	Odd
3	ME5313 Soft Computing Techniques	Odd
4	ME5752 Rapid Tooling and Industrial Applications	Even
5	ME5363 Intelligent Manufacturing Systems	Even
6	ME5368 Industry 4.o & IIoT	Even

Course Code: ME5701	Design For Additive Manufacturing	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

CO1	Identify the need of Design for Additive Manufacturing (DfAM)
CO2	Develop lattice structures using topology optimization
CO3	Apply DfAM guidelines in designing mass customised products
CO4	Identify design constraints and choose a Polymer AM process
CO5	Identify design constraints and choose a Metal AM process

Syllabus:

Introduction to Design for Additive Manufacturing (DfAM): Introduction to geometric modelling, Design freedom with AM, Need for Design for Additive Manufacturing (DfAM), CAD tools vs. DfAM tools, Requirements of DfAM methods, General Guidelines for DfAM, The Economics of Additive Manufacturing, Design to Minimize Print Time, Design to Minimize Post-processing.

Design Guidelines for Part Consolidation: Design for Function, Material Considerations, Number of Fasteners, Knowledge of Conventional DFM/DFA, Assembly Considerations, Moving Parts, Part redesign, Opportunities for part consolidation, challenges with part consolidation.

Design for Improved Functionality: Multi scale design for Additive manufacturing, Mass customization, Biomimetics, Generative design, Design of multi-materials and functionally graded materials.

Design for Minimal Material Usage: Topology Optimization, Modelling of Design space, defining design and manufacturing constraints, performing analysis for weight reduction, maximize stiffness, minimize displacement, Post-processing and Interpreting Results, Applications of TO, TO tools, Design of cellular and lattice structures, Design of support structures.

Computational Tools for Design Analysis: Considerations for Analysis of AM Parts, Material Data, Surface Finish, Geometry**,** Simplifying Geometry, Mesh-Based Versus Parametric Models, Build Process Simulation: Model Slicing, Contour Data Organization, Layer-by-Layer Simulation, Hatching Strategies, Scan Pattern Simulation and Tool Path Generation.

Design for Polymer AM: Anisotropy, Wall Thicknesses, Overhangs, Support Material, Accuracy, Tolerances, Layer Thickness, Resolution, Print Orientation, Warpage, over sintering, Hollowing Parts, Horizontal Bridges, Connections, Fill Style, holes, fillets, ribs, font sizes and small details.

Design for Metal AM: Powder Morphology, Powder Size Distribution, Material Characteristics, Designing to Minimize Stress concentrations, Residual Stress, Overhangs,

shrinkage, warpage and Support Material, Design Guidelines for Wall Thickness, Clearance Between Moving Parts, Vertical Slots, Circular Holes, fillets, channels, vertical Bosses, circular pins, External Screw Threads and part positioning.

Guidelines for AM Tooling Design: Mounting Fixtures and Guides**,** Conformal Cooling, Coolant Flow Strategies, Coolant Channel Shape, Coolant Channel Spacing, Minimise Print Time in Tooling.

Other AM Considerations: Designer Machine Operator Cooperation, Health and Safety, Material Exposure, Gas Monitoring, Gas Exhaust**,** Material Handling, Risk of Explosion, AM Part Standardization and Certification.

Text Books:

1. A Practical Guide to Design for Additive Manufacturing, Diegel, Olaf, Axel Nordin, and Damien Motte, Springer, 2020.
2. The 3D Printing Handbook: Technologies, Design and Applications, Redwood, Ben, Filemon Schoffer, and Brian Garret, 3D Hubs, 2017.

Reference Books:

1. Design for Advanced Manufacturing: Technologies and Process, Laroux K, Gillespie, McGrawHill, 2017.
2. Additive Manufacturing Technologies, Gibson, Ian, David W. Rosen, Brent Stucker, and Mahyar Khorasani, Springer, 2021.
3. Laser-Induced Materials and Processes for Rapid Prototyping, L.Lu, J. Y. H. Fuh and Y.S. Wong, Springer, 2001.
4. Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma, Springer, 2004.

Online Resources:

1. https://courses.gen3d.com/courses/enrolled/988400
2. https://markforged.com/resources/blog/design-for-additive-manufacturing-dfam
3. https://www.hubs.com/knowledge-base/how-design-parts-metal-3d-printing/
4. https://www.rapidmade.com/design-for-additive-manufacturing
5. https://all3dp.com/1/design-for-additive-manufacturing-dfam-simply-explained/#where-to-learn-dfam
6. https://engineering.purdue.edu/cdesign/wp/the-design-for-additive-manufacturing-worksheet/

Course Code: ME5702	ADDITIVE MANUFACTURING PROCESSES	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

CO1	Understand the working principles and process parameters of additive manufacturing processes
CO2	Explore different additive manufacturing processes and suggest suitable methods for building a particular component
CO3	Perform suitable post processing operation based on product repair requirement
CO4	Design and develop a working model using additive manufacturing Processes

Syllabus:

Introduction to Additive Manufacturing: Introduction to AM, AM evolution, Distinction between AM & CNC machining, Steps in AM, Classification of AM processes, Advantages of AM and Types of materials for AM.

Vat Photopolymerization AM Processes: Stereolithography (SL), Materials, Process Modeling, SL resin curing process, SL scan patterns, Micro-stereolithography, Mask Projection Processes, Two-Photon vat photopolymerization, Process Benefits and Drawbacks, Applications of Vat Photopolymerization, case studies.

Material Jetting AM Processes: Evolution of Printing as an Additive Manufacturing Process, Materials, Process Benefits and Drawbacks, Applications of Material Jetting Processes.

Binder Jetting AM Processes: Materials, Process Benefits and Drawbacks, Research achievements in printing deposition, Technical challenges in printing, Applications of Binder Jetting Processes.

Extrusion-Based AM Processes: Fused Deposition Modelling (FDM), Principles, Materials, Process Modelling, Plotting and path control, Bio-Extrusion, Contour Crafting, Process Benefits and Drawbacks, Applications of Extrusion-Based Processes, case studies.

Sheet Lamination AM Processes: Bonding Mechanisms, Materials, Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC), Gluing, Thermal bonding, LOM and UC applications, case studies.

Powder Bed Fusion AM Processes: Selective laser Sintering (SLS), Materials, Powder fusion mechanism and powder handling, Process Modelling, SLS Metal and ceramic part creation,

Electron Beam melting (EBM), Process Benefits and Drawbacks, Applications of Powder Bed Fusion Processes, case studies.

Directed Energy Deposition AM Processes: Process Description, Material Delivery, Laser Engineered Net Shaping (LENS), Direct Metal Deposition (DMD), Electron Beam Based Metal Deposition, Processing-structure-properties, relationships, Benefits and drawbacks, Applications of Directed Energy Deposition Processes. Friction stir additive manufacturing**:** process, parameters, advantages, limitations and applications, Additive friction stir deposition process: principle, parameters, applications, functionally graded additive manufacturing components, Case studies. **Wire Arc Additive Manufacturing:** Process, parameters, applications, advantages and disadvantages, case studies.

Materials science for AM - Multifunctional and graded materials in AM, Role of solidification

rate, Evolution of non-equilibrium structure, microstructural studies, Structure property relationship, case studies.

Post Processing of AM Parts: Support Material Removal, Surface Texture Improvement, Accuracy Improvement, Aesthetic Improvement, Preparation for use as a Pattern, Property Enhancements using Non-thermal and Thermal Techniques, case studies.

Guidelines for Process Selection: Introduction, Selection Methods for a Part, Challenges of Selection, Example System for Preliminary Selection, Process Planning and Control.

Learning Resources:

Text Books:

1. 3D Printing and Additive Manufacturing: Principles & Applications, Chua Chee Kai, Leong Kah Fai, World Scientific, 2015, 4th Edition
2. Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing", Ian Gibson, David W Rosen, Brent Stucker, 2nd Edition, Springer, 2015

Reference Books:

1. Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma, Springer, 2004
2. Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, D.T. Pham, S.S. Dimov, Springer, 2001.
3. Rapid Prototyping: Principles and Applications in Manufacturing, Rafiq Noorani, John Wiley & Sons, 2006.
4. Additive Manufacturing, Amit Bandyopadhyay Susmita Bose, CRC Press Taylor & Francis Group, 2020.
5. C.P Paul, A.N Junoop, "Additive Manufacturing: Principles, Technologies and Applications, Second Edition, McGrawHill, 2021.
6. Additive Manufacturing: A Tool for Industrial Revolution 4.0, M. Manjaiah, K. Raghavendra, N. Balashanmugam, J. Paulo Davim, Woodhead Publishing, Elsevier, 2021

Online resources:

1. https://www.nist.gov/additive-manufacturing
2. https://www.metal-am.com/
3. http://additivemanufacturing.com/basics/
4. https://www.3dprintingindustry.com/
5. https://www.thingiverse.com/
6. https://reprap.org/wiki/RepRap

Course Code: ME5313	SOFT COMPUTING TECHNIQUES	3-0-0:3

Pre-Requisites: NIL

Course Outcomes:

CO1	Classify and differentiate problem solving methods and tools.
CO2	Apply A*, AO*, Branch and Bound search techniques for problem solving.
CO3	Formulate an optimization problem to solve using evolutionary computing methods.
CO4	Design and implement GA, PSO and ACO algorithms for optimization problems in Mechanical Engineering.
CO5	Apply soft computing techniques for design, control and optimization of Manufacturing systems.

Syllabus:

Problem Solving Methods and Tools: Problem Space, Problem solving, State space, Algorithm's performance and complexity, Search Algorithms, Depth first search method, Breadth first search methods their comparison, A*, AO*, Branch and Bound search techniques, p type, Np complete and Np Hard problems.

Evolutionary Computing Methods: Principles of Evolutionary Processes and genetics, A history of Evolutionary computation and introduction to evolutionary algorithms, Genetic algorithms, Evolutionary strategy, Evolutionary programming, Genetic programming.

Genetic Algorithm and Genetic Programming: Basic concepts, working principle, procedures of GA, flow chart of GA, Genetic representations, (encoding) Initialization and selection, Genetic operators, Mutation, Generational Cycle, applications.

Swarm Optimization: Introduction to Swarm intelligence, Ant colony optimization (ACO), Particle swarm optimization (PSO), Artificial Bee colony algorithm (ABC), Other variants of swarm intelligence algorithms.

Advances in Soft Computing Tools: Fuzzy Logic, Theory and applications, Fuzzy Neural networks, Pattern Recognition, Differential Evolution, Data Mining Concepts, Applications of above algorithms in manufacturing engineering problems.

Deep Neural Networks: Neuron, Nerve structure and synapse, Artificial Neuron and its model, activation functions, Neural network architecture: single layer and multilayer feed forward networks, recurrent networks. Back propagation algorithm, factors affecting back propagation training, applications.

Application of Soft Computing to Mechanical Engineering/Production Engineering Problems: Application to Inventory control, Scheduling problems, Production, Distribution, Routing, Transportation, Assignment problems.

Text Books:

1. Soft Computing Integrating Evolutionary, Neural and Fuzzy Systems, Tettamanzi Andrea, Tomassini and Marco, Springer, 2001.
2. Artificial Intelligence, Elaine Rich, McGraw Hill, 2/e, 1990.
3. Multi-objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, John Wiley and Sons, 2001.
4. Optimization for Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, Ltd, 2012

Course Code: ME5752	RAPID TOOLING AND INDUSTRIAL APPLICATIONS	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

CO1	Understand the working principle and process parameters of rapid tooling methods
CO2	Identify the errors during development of tool and select the suitable compensatory methods
CO3	Apply the suitable tooling method for the given industrial application
CO4	Design and fabricate the tool for the given medical application
CO5	Design and fabricate the tool for the given automobile application

Syllabus:

Introduction: Conventional Tooling, Rapid Tooling, Differences between Conventional and Rapid Tooling, Classification of Rapid Tooling: Direct and Indirect Tooling methods; Soft, Bridge (firm) and Hard Tooling methods.

Indirect Methods for Rapid Tool Production and Rapid Bridge Tooling: Introduction to Bridge tooling, CAFÉ Bridge tooling, Direct AIM Rapid Bridge tooling, Rapid Tool Rapid Bridge tooling, Shrinkage Variation, Random-noise Shrinkage.

Rapid Tooling Process Modeling: Introduction to modeling, Concurrent Rapid Product and Process Development, Finite Element Modeling and Simulation, Injection-moulding, Die-casting, Blow-moulding, Thermo-forming Processes modeling.

The Express Tool Process: Introduction, High-Thermal-Conductivity Materials, Conformal Cooling Channels, The Express Tool Process, Finite-Element Analysis of Express Tools, Express Tool Process Characteristics, Case studies of Express Tools.

Direct Soft Tooling/Firm Tooling Methods: Role of direct soft tooling methods in tool production, SLS of Sand Casting & Copper PA Moulds, EOS Direct Croning^{TM} Process, Direct AIM (Direct ACES TM Injection Moulds), SL Composite Tooling, 3DP^{TM} Ceramic Shells, Topographic Shape Formation (TSF) tools.

Indirect Soft Tooling/Firm Tooling Methods: Role of indirect soft tooling methods in tool production, Metal Deposition Tools, Silicon rubber mould/RTV/Vacuum Casting, Epoxy tools, Spin casting with Vulcanized Rubber moulds, Castable Resin moulds, Castable Ceramic moulds, Plaster moulds, Casting (Investment/Die/Spin/Sand Castings).

Direct Hard Tooling Methods: Role of Direct Hard tooling methods in tool production, EOS DirectTool/ Direct Metal Laser Sintering, DTM RapidTool, LOM Tooling in Ceramic, ProMetal Rapid Tooling, Laser Engineered Net Shaping (LENS).

Indirect Hard Tooling Methods: Role of indirect hard tooling methods in tool production, Fusible metallic cores, 3D Keltool, Cast Aluminum and Zinc Kirksite Tooling, EDM Electrodes, Ecotool**.**

The Role of Rapid Tooling in Investment-Casting Applications: Introduction, Rapid Tool Making for investment Casting, Rapid tooling for developing Casting Applications, BELL Helicopter 427 Program

The Role of Rapid Tooling in Sand-Casting Applications: Sand casting Process, Tool Design and Construction for Sand Casting, Sand Casting Dimensional Control, Tooling Alternative Selection Case Studies.

Rapid Tooling in the Medical Device Industry: Introduction, Investment Casting and Conventional Wax Pattern Tooling, Conventional Tooling Manufacture Vs. Rapid Tooling Manufacture, Medical Case studies like Hip Stem and Knee implants.

Rapid Tooling in the Automotive Industry: Approaching Niche Vehicle Markets, Accelerating Product Developments, Utilizing Rapid Prototyping and Manufacturing, Machining Laminates, Rapid Prototype Stages, Subsequent Casting Operations, Rapid Tooling Developments, Case Studies.

Others: The Future of Rapid Manufacturing and Case studies related to Rapid Tooling other Industrial Applications.

Text Books:

1. Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping & Rapid Tooling, D.T. Pham and S.S Dimov, Springer, 2001.
2. Rapid Tooling Technologies and Industrial Applications, Peter Hilton and Paul F Jacobs, Marcel Dekker Inc, New York, 2001.

Reference Books:

1. Rapid Tooling Guidelines for Sand Casting, Wanlong Wang, Henry W. Stoll and James G. Conley, Springer, 2010.
2. Understanding Additive Manufacture: Rapid Prototyping, Rapid Tooling and Rapid Manufacture Andreas Gebhardt, Hanser Publishers, 2013.

Online Resources:

1. https://www.hubs.com/blog/3d-hubs-rapid-tooling/
2. https://www.rapiddirect.com/blog/rapid-tooling-manufacturing/

Course Code: ME5363	INTELLIGENT MANUFACTURING SYSTEMS	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

CO1	Develop reachability graphs for various manufacturing system problems using petri net models
CO2	Develop knowledge representation to establish models for processing
CO3	Apply clustering techniques to identify the variations in information sharing
CO4	Apply machine learning techniques for various real life applications in manufacturing systems
CO5	Evaluate block chain technology in the context of manufacturing systems design

Syllabus:

Petri Nets - Key concepts and definitions, principles of net theory, Place/Transition Systems and Elementary Net (EN) Systems. Token game, reachability, state graph, behavioural properties like deadlock and boundedness, behavioural equivalence and normal forms. Elementary Net Systems: Causality, conflict, concurrency, and confusion. Examples of Petri net models. Examples in manufacturing Systems

Components of Knowledge Based Systems: - Basic Components of Knowledge Based Systems, Knowledge Representation, Comparison of Knowledge Representation Schemes, Interference Engine, Knowledge Acquisition, Clustering. Examples in manufacturing Systems Cloud Manufacturing and Networking with TCP/IP: Introduction to cloud computing: cloud models, cloud service examples, cloud based services & applications. Introducing TCP/IP, IP Addressing and Related Topics, Data Link and Network Layer TCP/IP Protocols, Internet Control Message Protocol (ICMP), Transport Layer TCP/IP Protocols, Basic TCP/IP Services.

Machine Learning: Machine Learning – Concept, Artificial Neural Networks, Biological and Artificial Neuron, Deep Nets, Applications in manufacturing; Use of probability and fuzzy logic for machine thinking, Examples in manufacturing Systems.

Agent and Multi-agent systems: Agents, agent definitions and classification, multi-agent systems, Models of agency, architectures and languages, Agent communication and interaction protocols. Examples in manufacturing Systems

Block Chain Technology: Basic Concepts, Trust- The need for trust, Forms of trust, The problem space for block chain. Cryptography - Information security as a form of trust, Public and Private keys, Digital signatures, Hashing. Examples in manufacturing Systems

Text Books:

1. Automation, Production Systems and CIM, Groover M.P.,Prentice-Hall, New Delhi, 2009.
2. A Comprehensive guide to AI and Expert Systems, Robert Levine , McGraw Hill Inc, 1986.
3. Automation, Production Systems and Computer Integrated Manufacturing, Mikell P. Groover, PHI, 2008, 8th edition.
4. Intelligent Manufacturing Systems, Andrew Kusiak/Prentice Hall.
5. Guide to TCP/IP, Ed Tittel, Laura Chappell, Third Edition. Course Technology Incorporated, 2007,

6. Automated Planning- Theory and Practice, Malik Ghallab Malik, Morgan Kaufmann, 2004.
7. Machine Learning, Mitchell T, Mc-Graw Hill, 2012.

Course Code: ME5368	INDUSTRY 4.o & IIoT	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

CO1	Explore how Industry 4.o will change the current manufacturing technologies and processes by digitizing the value chain
CO2	Understand the drivers and enablers of Industry 4.o
CO3	Learn about various IIoT-related protocols
CO4	Build simple IIoT Systems using Arduino and Raspberry Pi

Syllabus:

Introduction to Industry 4.o: Industry 4.o: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Mass Customization, Smart and Connected Business Perspective, Smart Factories, Industry 4.o: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis

Introduction to IIoT: Architectural Overview, Design principles and needed capabilities, IoT Applications, Sensing, Actuation, Basics of Networking, M2M and IoT Technology Fundamentals- Devices and gateways, Data management, Business processes in IoT, Everything as a Service (XaaS), Role of Cloud in IoT, Security aspects in IoT.

Elements of IIoT: Hardware Components- Computing (Arduino, Raspberry Pi), Communication, Sensing, Actuation, I/O interfaces. Software Components- Programming API's (using Python/Node.js/Arduino) for Communication Protocols-MQTT, ZigBee, Bluetooth, CoAP, UDP, TCP.

IIoT Application Development: Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Device data storage- Unstructured data storage on cloud/local server, Authentication, authorization of devices. Case Studies: IoT case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation.

Text Books:

1. Introduction to Industrial Internet of Things and Industry 4.0, Sudip Misra, Chandana Roy, Anandarup Mukherjee, CRC Press, 2020.
2. Ïnternet of Things - A Hands on Approach, Vijay Madisetti, Arshdeep Bahga, University Press.
3. Introduction to Internet of Things: A practical Approach, Dr. SRN Reddy, Rachit Thukral and Manasi Mishra, ETI Labs.
4. The Internet of Things: Enabling Technologies, Platforms, and Use Cases, Pethuru Raj and Anupama C. Raman, CRC Press.
5. Designing the Internet of Things, Adrian McEwen, Wiley

Reference Books:

1. Internet of Things: Architecture and Design, Raj Kamal, McGraw Hill.
2. Getting Started with the Internet of Things, Cuno Pfister, O Reilly Media.