CURRICULUM & SYLLABI
M. Tech. WELDING TECHNOLOGY AND NON-DESTRUCTIVE TESTING

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL
WARANGAL, TELANGANA

Table of Contents

Vision and Mission of the Institute **3**
Vision and Mission of the Department **3**
Program Educational Objectives **4**
Program Outcomes (POs) **5**
CURRICULUM **6**
SYLLABI **9**

Vision and Mission of the Institute

National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department

Metallurgical and Materials Engineering

VISION

Attain global recognition in research and training to meet challenging needs of Metallurgical and Materials Engineering with ethical and moral responsibility towards society

MISSION

- Provide outstanding technical education for analysis, design and operation of metallurgical and materials systems.
- Keep abreast with rapid strides of technology and improve academic standards through innovative teaching and learning processes.
- Engage in quality research in metallurgical, materials and allied engineering areas.
- Develop academic linkages with leading industries for mutual benefit.

Program: M. Tech – Welding Technology and Non-destructive Testing

Program Educational Objectives

PEO-1	Design and develop welded structure fabrication systems for all materials to fulfil industrial and societal needs.
PEO-2	Formulate innovative inspection solutions for engineering materials, components and systems.
PEO-3	Practice industrial standards, safety measures and frame guidelines for manufacturing industries.
PEO-4	Pursue life-long learning by enhancing knowledge and skills for professional advancement and sustainable growth.

Program Articulation Matrix

PEO / Mission Statements	**PEO1**	**PEO2**	**PEO3**	**PEO4**
Provide outstanding technical education for analysis, design and operation of metallurgical and materials systems.	3	3	2	2
Keep abreast with rapidstrides of technology and improve academic standards through innovative teaching andlearning processes.	2	3	2	2
Engage in quality research in metallurgical, materialsand allied engineering areas.	3	3	3	2
Develop academic linkages with leading industries for mutual benefit.	2	2	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: M. Tech. – Welding Technology and Non-Destructive Testing

Program Outcomes (POs)

PO1	Demonstrate professional skills in materials joining for manufacturing industry.
PO2	Perform non-destructive examination of industrial components and structures.
PO3	Develop methodologies for life assessment and enhancement of engineering structures.
PO4	Perform independent research to evolve novel joining and inspection solutions.
PO5	Write and present professional and technical reports efficiently.
PO6	Practice industrial standards, professional ethics and project management skills.

CURRICULUM
M.Tech Welding Technology and Non-destructive Testing

1st Semester

S. No	Course code	Course title	L-T-P	Credits
1	MM26001	Welding Processes	3-0-0	3
2	MM26003	Ferrous Welding Metallurgy	2-1-0	3
3	MM26005	Non-destructive Testing Techniques	3-0-0	3
4		Professional Elective- I	3-0-0	3
5		Professional Elective- II	3-0-0	3
6	MM26007	Welding Processes Laboratory	0-1-2	2
7	MM26009	Non-destructive Testing Laboratory	0-1-2	2
			Total credits	**19**

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM26002	Non-ferrous Welding Metallurgy	3-0-2	4
2	MM26004	Advanced Nondestructive Testing Techniques	3-0-0	3
3		Professional Elective- III	3-0-0	3
4		Professional Elective- IV	3-0-0	3
5		Professional Elective- V	3-0-0	3
6	MM26006	Advanced Experimental Techniques Laboratory	0-1-2	2
7	MM16008	Mechanical Behavior of Materials Laboratory	0-1-2	2
8	MM26096	Minor Project	0-0-0	2
			Total Credits	**22**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM26089	Seminar and Technical Writing	0-0-0	2
2	MM26093	Comprehensive Viva-Voce	0-0-0	2
3	MM26097	Dissertation: Part-A	0-0-0	8
4	MM26091	Summer Internship/ Research Experience	0-0-0	2
		Total Credits		**14**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM26098	Dissertation: Part-B	0-0-0	12
		Total Credits		**12**

Program Elective Courses:

Elective – I, II (I Year, I Semester)		
S.No.	**Code**	**Course Title**
1	MM26021	Design of Weldments
2	MM26023	Joining and NDT of Ceramics, Polymers and Composites
3	MM26025	Corrosion of Weldments
4	MM26027	Advanced Experimental Techniques
5	MM26029	Fatigue and Fracture Mechanics
6	MM16041	Strengthening Mechanisms

Elective – III, IV, V (I Year, II Semester)		
S. No.	**Code**	**Course Title**
1	MM26022	Residual Stresses and Distortion
2	MM26024	Welding Application Technology
3	MM26026	Statistics, Quality and Reliability
4	MM26028	Mechanical Behavior of Weldments
5	MM26030	Computational Methods for Welding and Joining
6	EC16062	Signal and Image Processing
7	MM16022	Additive Manufacturing
8	MM16038	Design and Selection of Advanced Materials
9	MM16024	Surface Engineering and Coating Technologies
10	MM16040	Metallurgy of Steels

SYLLABI

M. Tech. Welding Technology and Non-destructive Testing

1st Semester

MM26001 **3-0-0 (3)**

Welding Processes

Pre-Requisites: **None**

Course Outcomes:

CO-1	Compare the working principles of traditional and modern welding processes
CO-2	Relate welding process parameters with weld quality.
CO-3	Identify various welding defects and remedial measures
CO-4	Select a suitable welding process for a given application.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	1	-	-
CO-2	3	-	-	1	-	-
CO-3	3	2	1	1	-	-
CO-4	3	-	-	1	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamentals of welding: soldering and brazing, classification of welding processes, types of weld joints, welding positions, welding arc characteristics, arc initiation, power source characteristics.

Manual metal arc welding: principles of operation, electrode designation, types of electrodes, and their applications, Gas tungsten arc welding (GTAW): polarities in GTAW, tungsten electrodes, shielding gases, filler wire, applications, variations in GTAW (pulsed and hot wire), plasma arc welding (PAW): modes of PAW (Micro- mode, low current melt-in mode, and key- hole mode), applications, gas metal arc welding (GMAW): modes of metal transfer (Spray, globular, short-circuit and pulsed spray), self-regulating arc, applications. Fluxed core arc welding (FCAW): variants in FCAW (self-shielded and gas shielded), types of electrodes, applications, submerged arc welding (SAW): classification of flux and electrodes in SAW, applications.

Gas welding processes: fuel gases, oxy acetylene welding, types of flames, applications, other welding processes: resistance welding (RW): principles of operation, types of RW, spot welding, resistance spot welding cycle, seam welding, projection, flash butt and percussion.

Electron beam welding (EBW): Laser beam welding (LBW): physics of lasers, types of lasers, operation of laser welding setup, advantages and limitations, applications.

Solid-state welding: need for solid-state welding, types of solid-state welding, Friction welding: variations, steps in friction welding, types and applications. Friction stir welding: principles of operation, metal flow phenomena, tools, process variables and applications, explosive, diffusion and ultrasonic welding, principles of operation, process characteristics and applications.

Welding defects: discontinuity vs defects, incomplete fusion, insufficient penetration, weld undercut, weld cracks, weld porosity, slag inclusions, tungsten inclusion, reinforcement, overlap, burn through, crater cracks, spatter, arc strike.

Learning Resources:

Text Books:

1. Cary, Howard B. and Scott C. Helzer, Modern Welding Technology. Upper Saddle River, New Jersey: Pearson Education, USA, 2005.
2. Sindo Kou, Welding metallurgy, John Willey, 2003, 2nd edition, USA.
3. J.F. Lancaster, Metallurgy of Welding, Abington Publishing, 6th edition, England. 1999.
4. Richard Little, Welding and Welding Technology, McGraw Hill, 1st edition, 2001.
5. Metals Handbook-Welding, Brazing and Soldering, American Society for Metals, 10th edition, Vol. 6, 1993.
6. Inspection and testing of weld joints Welding handbook, American Welding Society, 7th edition, USA, 1983.

Reference Books:

1. Metals Handbook-mechanical testing and evaluation, American Society for Metals, Volume 8, USA, 1993.
2. Welding handbook, American Welding Society, 8th edition, vol.1 & 2, USA, 1987.

Other Suggested Readings:

1. https://www.twi-global.com/technical-knowledge/faqs/what-is-welding
2. https://nptel.ac.in/courses/113/106/113106087/

MM26003 **2-1-0 (3)**

Ferrous Welding Metallurgy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the physical metallurgy of ferrous alloys.
CO-2	Discuss the factors that influence the microstructure and properties of weldments.
CO-3	Evaluate the impact of welding on the properties of ferrous alloys.
CO-4	Apply the principles of ferrous welding metallurgy to real-world problems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Ferrous Metallurgy: Classification, phase diagrams and their applications, microstructure of ferrous metals, solidification and cast structure, heat treatment and phase transformations, CCT diagrams, alloying elements effect on Fe-C phase diagrams.

Weld microstructure: Welding metallurgy and weldability, zones of weldment, microstructural changes during welding, solidification and cooling rate effects on microstructure, grain growth and its impact on properties.

Effects of welding: The role of alloying elements. Heat flow, temperature distribution, and cooling rate and thermal cycle, Δt8/5. Thermal severity number. Impact of heat input, process, joint geometry, plate thickness, peak temperature and preheat. Weld dilution, Multi-pass welding microstructure.

Welding of steels: types of steels: plain carbon steels, alloy steels, tool steels. welding of automobile steels, structural steels, quenched and tempered steels, heat resistant steels, and cast irons. microstructure, pre and post weld preparation, common welding techniques, challenges and case studies. metallurgical defects and mitigation, cracking phenomena in ferrous materials, prevention and remedial techniques for cracking in ferrous alloy welds. classification, physical metallurgy of stainless steels, Schaeffler's diagram, welding fillers, techniques for stainless steel welding.

Weld Properties: Tensile, compressive, and bending properties, fatigue and fracture mechanics, corrosion behavior of welded ferrous metals.

Case Studies and Practical Examples: Case studies of real-life welding projects, practical examples of welding processes and procedures.

Learning Resources:

Text Books:

1. J.G. Lippold and D.J. Kotecki, "Metallurgy and Welding for Engineers", 2nd edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2005.
2. J.C. Lippold and D.J. Kotecki, "Welding Metallurgy and Weldability of Stainless Steels", John Wiley & Sons, Inc., Hoboken, New Jersey, 2005.
3. Sindo Kou, "Welding Metallurgy", 2nd edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2003.
4. J.F. Lancaster, "Practical Welding Metallurgy", 2nd edition, Woodhead Publishing Limited, Cambridge, England, 2005.

Reference Books:

1. Metals Handbook Desk Edition, American Society for Metals, USA, 1998.
2. Welding handbook, American Welding Society, 8th edition, vol.5, USA, 2011.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc23_me49/preview.

MM26005 **3-0-0 (3)**

Nondestructive Testing Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Compare destructive testing and non-destructive testing techniques.
CO-2	Discuss the effect of NDT parameters on defect detection.
CO-3	Evaluate the NDT data.
CO-4	Select an NDT technique to characterize a defect.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	–	3	3	1	–	1
CO-2	–	3	3	1	–	1
CO-3	–	3	3	1	–	2
CO-4	–	3	3	1	–	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Scope and advantage of non-destructive testing (NDT), Comparison of NDT with destructive testing (DT), surface vs. volumetric defects; principles, nomenclature, classification.

Advantages, limitations and instrumentation: visual testing, pressure and leak testing, penetrant testing, magnetic particle testing, eddy current testing, ultrasonic testing, radiography; reference and calibration blocks for various NDT methods, codes, standards and specifications (ASME, ASTM, AWS etc.) of NDT testing.

Learning Resources:

Text Books:

1. Non-Destructive Examination and Quality Control, ASM International, Vol.17, 9th edition (1989)
2. J. Prasad and C. G. K. Nair, Non-Destructive Test and Evaluation of Materials, Tata McGra Hill Education, 2nd edition (2011).
3. B. Raj, T. Jayakumar and M. Thavasimuthu, Practical Non Destructive Testing, Alpha Science International Limited, 3rd edition (2002).
4. T. Tangachari, J. Prasad and B.N.S. Murthy, Treatise on non-destructive testing and evaluation, Navbharath Enterprises, Vol.3, (1983).

Reference Books:

1. C. Hellier, Handbook of NonDestructive Evluation, McGraw-Hill Professional, 1st edition (2001).

2. J. Thomas Schmidt, K. Skeie and P. MacIntire, ASNT Non Destructive Testing Handbook: Magnetic Particle Testing, American Society for Nondestructive Testing, American Society for Metals, 2nd edition (1989).
3. V. S. Cecco, G. V. Drunen and F. L. Sharp, Eddy current Manual: Test method, Vol.1, Chalk River Nuclear Laboratories (1983).
4. B.P.C. Rao, Practical Eddy Current Testing, Alpha Science International Limited (2006).
5. N. A. Tracy, P. O. Moore, Non-Destructive Testing Handbook: Liquid Penetrant Testing, Vol. 2, American Society for Nondestructive Testing, 3rd edition (1999).

Other Suggested Readings:

1. https://www.youtube.com/watch?v=oIG_NDb2g3U&list=PLLy_2iUCG87DDug5sIyc0yZAETChtMvG0
2. www.ndt.edu
3. www.nde-ed.org

MM26007 **0-1-2 (2)**

Welding Processes Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Demonstrate prerequisites for welding.
CO-2	Perform fusion and solid-state welding processes.
CO-3	Evaluate the microstructure and mechanical properties of weldments.
CO-4	Prepare comprehensive reports on experiments carried out.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	1	2	2
CO-2	3	-	-	1	-	2
CO-3	3	1	2	1	2	2
CO-4	3	-	-	1	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Welding: Preparation of weld joint using gas welding, manual metal arc welding, submerged arc welding; resistance welding; heat input calculation in arc welding; preparation of all-weld tensile test specimen and characterization of weldments, study of microstructure of fusion zone, heat affected zone and base metal of the welded specimen, determine the tensile strength and ductility of a weldment as per ASTM standards, hardness profile across the weldment.

Text Books:

1. Welding Process Laboratory manual

2. Cary, Howard B. and Scott C. Helzer, Modern Welding Technology. Upper Saddle River, New Jersey: Pearson Education, USA, 2005.

Reference Books:

1. Welding Handbook, Vol 2- Welding Processes, 9th Ed, AWS, 2004.

2. ASM International Handbook Committee. ASM Handbook, Volume 15-Casting. ASM International., 2008.

MM26009 **0-1-2 (2)**

Nondestructive Testing Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Perform inspection of engineering components using non-destructive testing.
CO-2	Interpret radiographs for defect analysis.
CO-3	Calibrate the Non -Destructive testing equipment's for evaluation.
CO-4	Identify NDT methods for component inspection.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	–	3	2	1	2	2
CO-2	–	3	2	1	2	2
CO-3	–	3	2	1	2	2
CO-4	–	3	2	1	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Nondestructive Testing: Visual inspection of engineering components, Inspection of internal defects in pipes, Inspection of components using dye penetrant testing, Inspection on non-magnetic/magnetic materials by eddy current method, Inspection and evaluation of subsurface flaws using magnetic particle testing, Inspection of engineering components by magnetic particle testing (wet and dry methods), Calibration of ultrasonic testing equipment using calibration blocks, Subsurface defect detection in welded plates using ultrasonic angle beam testing, Inspection and interpretation of radiographs

Learning Resources:

Text Books:

1. NDT Laboratory Manual.

Reference Books:

1. J. Prasad and C. G. K. Nair, Non-Destructive Test and Evaluation of Materials, Tata McGraw-Hill Education, 2nd edition (2011).
2. Practical Non-Destructive Testing, Baldev Raj, T.Jayakumar, M.Thavasimuthu, Narosa Publishing House, 2014.
3. Non-Destructive Testing Techniques, Ravi Prakash, New Age International Publishers, 2010, 1st revised edition.

Other Suggested Readings:

1. www.ndt.edu
2. www.nde-ed.org

2nd Semester

MM26002 **3-0-2 (4)**

Non-Ferrous Welding Metallurgy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the phase transformations in non-ferrous alloys.
CO-2	Explain the influence of welding parameters on weldment microstructure and properties.
CO-3	Identify welding defects and remedial measures
CO-4	Select welding processes for non-ferrous alloys
CO-5	To demonstrate the gas tungsten arc (GTA) welding practices of Al, Ti and Ni base alloys
CO-6	To evaluate the microstructure and hardness profile of weldments.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1
CO-5	3	-	-	2	-	1
CO-6	3	-	-	2	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Welding of Aluminium alloys: Classification of wrought and cast alloys, designations, non-heat treatable and heat treatable alloys, role of alloying elements, strengthening mechanisms, different welding processes used for aluminium alloys, problems in Al welding, porosity formation in Al welds, hydrogen solubility, Oxide film removal, surface preparation, solidification cracking in Al alloys, grain refinement, filler metal selection, partially melted zone (PMZ), liquation cracking, softening of HAZ, Al welding distortion.

Welding of Titanium alloys: classification of titanium alloys, Applications, Influence of alloying elements, hydrogen solubility in Ti Alloys, Al equivalent, Mo equivalent, Phase transformations, CCT diagrams, different welding processes used for titanium alloys, shielding gases, welding problems, post weld heat treatments, grain boundary alpha problem, issues in post-weld ageing of metastable β alloys, defects in Ti welding, surface colour in Ti welds, hydrogen embrittlement, fillers used in Ti welding

Welding of Magnesium alloys: classification of magnesium alloys, ASTM designation, applications, role of alloying elements, different welding processes used for magnesium alloys, oxide layer problem, shielding gases, surface preparation, loss in HAZ strengthening, stress corrosion cracking, filler metals, welding defects in Mg alloys.

Welding of Ni-base alloys: classification of Ni and Ni alloys, Super alloys, applications, role of alloying elements, strengthening mechanisms, different welding processes used for Ni alloys, shielding gases, filler

metals, welding problems, post weld ageing treatments, reversion of precipitate and loss of strength, strain age cracking, solidification cracking, HAZ liquation cracking

Welding of copper alloys: classification of copper and copper alloys, applications, role of alloying elements, factors affecting weldability, different welding processes used for copper alloys, filler metals, shielding gases, joint designs

Welding of Niobium alloys: Nb alloys, surface preparation, weldability, GTA Welding and brazing

Welding of zirconium alloys: grades of Zr, physical metallurgy of Zr, applications, different welding processes used for zirconium alloys, surface preparation, filler metals

List of Experiments:

1. Fabricate a bead-on plate or butt joint using titanium plates, employing the gas tungsten arc welding process with trailing and backing gases. Analyze the microstructure of the welded joint.

2. Fabricate a bead-on plate or butt joint using aluminum plate, utilizing the gas tungsten arc welding process. Examine the microstructure of the welded joint.

3. Fabricate a bead-on plate or butt joint using nickel plate, employing the gas tungsten arc welding process. Investigate the microstructure of the welded joint.

4. Investigate the influence of heat input on the microstructure of a welded joint in the gas tungsten arc welding process.

5. Explore the relationship between the microstructure and hardness profile of the welded joint.

Learning Resources:

Text Books:

1. Gene Mathers, The welding of aluminium and its alloys. Woodhead Publishing Limited, Abington Hall, Abington Cambridge CB1 6AH, England, 2002.
2. I. J. Polmear, Light alloys- from traditional alloys to nanocrystals. Butterworth-Heinemann Linacre House, Jordan Hill, 2006
3. Froes. F, Titanium: physical metallurgy, processing, and applications. ASM international, 2015.
4. Cary, Howard B. and Scott C. Helzer, Modern Welding Technology. Upper Saddle River, New Jersey: Pearson Education, USA, 2005.
5. Sindo Kou, Welding metallurgy, John Willey, 2003, 2nd edition, USA.

Reference Books:

1. Metals Handbook Desk Edition, American Society for Metals, USA, 1998.
2. Welding handbook, American Welding Society, 8th edition, vol.5, USA, 2011.

Other Suggested Readings:

1. https://www.twi-global.com/technical-knowledge/faqs/faq-i-have-to-weld-a-non-ferrous- metal-what-does-non-ferrous-mean-and-what-thing
2. https://onlinecourses.nptel.ac.in/noc23_me49/preview.

MM26004 **3-0-0 (3)**

Advanced Nondestructive Testing Techniques

Pre-Requisites: None

Course Outcomes:

CO-1	Describe the principles of advanced non-destructive testing methods.
CO-2	Discuss thermomechanical behavior of materials through thermography.
CO-3	Apply NDT techniques for real-time structural monitoring.
CO-4	Suggest advanced NDT techniques for defect evaluation in energy, nuclear, and aerospace sectors.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	–	3	3	1	–	1
CO-2	–	3	3	1	–	1
CO-3	–	3	3	2	–	2
CO-4	–	3	3	2	–	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Acoustic emission testing (AET): Principles, applications, advantages and disadvantages, signal propagation, AE process chain, parameters, measurement chain, types of displays, noise, location calculation, inspection of composites, pressure vessels, steam turbines, power transformers.

Advanced ultrasonic testing: Principles of phased array ultrasonic probes and their characteristics, wedges, focal law, beam shaping and steering, scanning (A, B, C, D and S scans), TFM/FMC (total focusing method/ full matrix capture).

TOFD (time of flight diffraction): Theory and principles, data acquisition and interpretation.

Digital Radiography and Computed Tomography (CT): Principles and methods, process of image formation, image reconstruction algorithm, industrial applications, data acquisition system, Image quality, image artefacts.

Strain measurement and analysis: Principles, types of strain gauges, residual stress measurement in welding.

Learning Resources:

Text Books:

1. Non-destructive evaluation of materials by infrared thermography, X. P. V. Maldague, Springer-Verlag, 1993.

2. Emerging Technologies in Non-Destructive Testing, A.S. Paipetis, T. E Matikas and D. G. Aggelis, CRC Press, 2012.
3. Acoustic Emission Testing, C. U. Grosse, Springer, (2008).

Reference Books:

1. Non-Destructive Testing Handbook; Infrared and Thermal Testing, Vol-3, series III, X. P.V. Maldague, American Society for Non-Destructive Testing, 2001.
2. Non-Destructive Testing Handbook; Leak Testing, Vol - 1, series VI, C. N. Jackson and N. Sherlock, American Society for Non-Destructive Testing, 1998.
3. Non-Destructive Testing Handbook; Acoustic Emission Testing, Vol-6, series V, R. K.Miller and V.K.Hill, American Society for Non-Destructive Testing, 2005, 3rd edition.

Other Suggested Readings:

1. https://www.twitraining.com/home/programmes-and-courses/non-destructive-testing/advanced-ndt methods

MM26006 **0-1-2 (2)**

Advanced Experimental Techniques Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply microscopic techniques for microstructural and fracture analysis
CO-2	Analyze the chemical composition of materials through SEM-EDS.
CO-3	Quantify microstructural features using image analysis tool.
CO-4	Analyze X-ray diffraction data for determining crystallographic parameters
CO-5	Apply thermal analysis techniques to study the stability and transformation behavior ofmaterials

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	–	2	3	1	2	1
CO-2	–	2	3	1	2	1
CO-3	–	2	3	1	2	1
CO-4	–	2	3	1	2	1
CO-5	–	2	3	1	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Advanced Experimental Techniques: Study of cutting machine, mounting method, grinding and polishing and etching techniques for bulk sample for Metallographic Examination, Study of optical and scanning electron microscopes, Quantitative image analysis of phase fraction, grain size, nodularity and nodule count of an alloy, Determination of inter-lamellar spacing of pearlite using SEM, Study of microstructure of weld joint by using SEM, Fractography analysis using Scanning electron microscopy (SEM), Chemical analysis using energy dispersive X-ray analysis in SEM, Calculation of structure factor for different crystal structures and determination of crystal structure by X-ray Diffraction (XRD), Determination of crystallite size by XRD and stain by using XRD pattern, Study of TGA, DTA and DSC, Determination of mass change and phase transformation temperature of a given materials.

Learning Resources:

Text Books:

1. Yang Leng: Materials Characterization-Introduction to Microscopic and Spectroscopic Methods - John Wiley & Sons (Asia) Pte Ltd, 2008
2. ASM Handbook: Materials Characterization, ASM International, 2008.

Reference Books:

1. Materials Characterization Techniques Laboratory Manual.
2. Scanning electron microscope (SEM) instrumentation: Scanning Electron Microscopy and X-Ray Microanalysis. Springer, Goldstein JI, Newbury DE, Michael JR, Ritchie NW, Scott JH, Joy DCNew York, NY, 2018, 4th Edition.
3. Elements of X-Ray Diffraction, B.D.Cullity and S.R.Stock, 3rd Edition, Prentice Hall, NJ, 2001.

Other Suggested Readings:

1. https://youtu.be/KfQ4VNpWN4M
2. https://www.youtube.com/watch?v=vVm0ZW9zBtQ
3. https://www.youtube.com/watch?v=UuHofNW40Yw
4. https://www.youtube.com/watch?v=Mr9-1Sz_CK0
5. https://www.youtube.com/watch?v=ArPXfPjOJQc
6. https://www.youtube.com/watch?v=07iZ7-IEyYE
7. https://www.youtube.com/watch?v=yguvwX_ia_A&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=2

MM16008 **0-1-2 (2)**

Mechanical Behavior of Materials Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Operate mechanical testing equipment for measuring materials properties
CO-2	Analyze the data obtained from mechanical testing.
CO-3	Determine the fracture toughness of materials
CO-4	Assess high-temperature mechanical properties of alloys

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	2	2	-	3	-
CO-2	-	2	2	-	3	-
CO-3	-	2	2	-	3	-
CO-4	-	2	2	-	3	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Mechanical Characterizations: Hardness test, Tensile test, Compression test, Impact test, Wear and erosion test, Microhardness and indentation fracture toughness test, Fracture toughness test, Fatigue testing.

Learning Resources:

Text Books:

1. R. W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, 4th Edition, John Wiley & Sons Inc., 2012.
2. M.A. Meyers and K.K. Chawla: Mechanical Behavior of Materials, Prentice Hall Inc., New Delhi, 1999.
3. T. L. Anderson: Fracture Mechanics- Fundamentals and Applications, 3rd Edition, CRC Press, 2011.
4. G. E. Dieter: Mechanical Metallurgy, McGraw-Hill, 2002

Other Suggested Readings:

1. Mechanical Behavior of Materials Laboratory Manual
2. Hardness Testing Principles and Applications-ASM International (2011), Konrad Herrman
3. ASM Handbook, Volume 20, Materials Selection and Design. Materials Park, OH: ASM International, 1990.
4. ASM Handbook, Volume 8, Mechanical Testing and Evaluation. Materials Park, OH: ASM International, 1990.
5. ASTM E18-03: Standard Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials. West Conshohocken, PA : ASTM International, 2004.

MM26096 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution
CO-4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	3	3	-	3
CO-2	3	-	3	3	1	3
CO-3	3	-	3	3	2	3
CO-4	-	3	3	3	1	3
CO-5	-	3	3	3	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Identification of Problem Domain	10%
II	Study of Existing Systems and establishing clear objectives	15%
III	Planning of project and work distribution within the team	30%
IV	Proper Documentation and Technical Writing	25%
V	Presentation and Response to questions	20%

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II	X			
III		X	X	
IV				X
V				X

3rd Semester

MM26089 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	1	-	-	1
CO-2	3	-	1	-	-	1
CO-3	1	3	1	-	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Clarity on the topic	10%
II	List of lectures attended	30%
III	Report	30%
IV	Presentation	20%
V	Response to questions	10%

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3
I	X		
II	X		
III		X	
IV			X
V			X

MM26093 **0-0-0 (2)**

Comprehensive Viva-Voce

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Demonstrate the ability in problem solving
CO-3	Communicate effectively using engineering terminology

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	1	1	-	-
CO-2	3	3	1	1	-	-
CO-3	3	3	1	1	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

MM26097 **0-0-0 (8)**

Dissertation: Part-A

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a topic in advanced areas of welding technology and NDT.
CO-2	Review literature to identify gaps and define objectives and scope of the work.
CO-3	Employ the ideas from literature and develop research methodology.
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	1	-	3
CO-2	3	2	3	1	-	3
CO-3	3	3	3	3	3	3
CO-4	3	3	3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	15%
II	Literature Survey	30%
III	Defining the Objectives and Solution Methodology	20%
IV	Performance of the Task	35%

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X

MM26091 **0-0-0 (2)**

Summer Internship/ Research Experience

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	2	3
CO-2	2	2	2	2	2	3
CO-3	2	3	3	2	3	2
CO-4	2	2	2	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Every student has to undergo either a Summer Internship / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Relevance of the area of work	10%
II	Performance of the Task	30%
III	Crucial learnings from the work	30%
IV	Report Preparation	20%
V	Presentation and Response to questions	10%

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

4th Semester

MM26098 **0-0-0 (12)**

Dissertation: Part-B

Pre-Requisites: **Dissertation: Part-A**

Course Outcomes:

CO-1	Identify the materials and methods for carrying out experiments/develop a code.
CO-2	Execute the research methodology with a concern for society, environment and ethics
CO-3	Analyse, discuss and justify the results/trends and draw valid conclusions.
CO-4	Prepare the report as per recommended format and present the work orally adhering to stipulated time.
CO-5	Explore the possibility to publish/present a paper in peer reviewed journals/conference proceedings without plagiarism.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	3	2	3
CO-2	2	-	3	3	2	3
CO-3	3	-	3	3	2	3
CO-4	3	3	3	3	3	3
CO-5	3	3	3	-	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A. Weightage for each criterion will be determined by the panel and will be informed to the students.

Task	Description	Weightages
IV	Performance of the Task	30%
V	Dissertation Preparation	20%
VI	Review (Presentation & Understanding)	20%
VII	Viva-Voce	20%
VIII	Publications /Possibility of publication	10%

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
IV	X	X			
V			X		
VI				X	
VII				X	
VIII					X

Refer to M.Tech. – Regulations for any further information regarding Mid-term review, End Sem evaluation, Template for report preparation and plagiarism

Professional Electives

MM26021 **3-0-0 (3)**

Design of Weldments

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss welding symbols and their use.
CO-2	Analyze weldments for residual stress and its effects on the weldment performance.
CO-3	Evaluate weldment strength and reliability using design factors and stress analysis methods.
CO-4	Design durable weldments to sustain industrial service conditions.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Welding Symbols: Types of welding symbols, reading and interpreting welding symbols, symbol conventions and standards

Weld Residual Stress: Causes and effects of residual stress, measurement techniques for residual stress, mitigation techniques for residual stress

Stresses in weld joints and design: Stresses in butt and fillet joints, normal / shear stress, static, elevated temp strengths, impact behaviour, types of failure, structural details standards and specifications. construction of boilers, pressure vessels, pipelines, etc.

Weld Strength Calculations: Basic concepts of weld strength, design factors affecting weld strength, calculation methods for weld strength

Stress Analysis of Welds: Types of weld stress, stress analysis methods, fatigue life calculations

Weld Design for Fatigue: SN curve, fatigue failure modes in welds, fatigue strength of welded joints, design considerations for fatigue resistance, effect of residual stresses, fatigue resistance improvement.

Applications and Case Studies: Industrial applications, case studies of weldment design, emerging trends in weldment design, future directions in weldment design

Learning Resources:

Text Books:

1. "Welding Symbols Quick Card" by Builder's Book, Inc. (2011)
2. "Residual Stress, Thermomechanics & Infrared Imaging, Hybrid Techniques and Inverse Problems, Volume 9: Proceedings of the 2015 Annual Conference on Experimental and Applied Mechanics" edited by Helena Jin and K. Elliott Cramer (2015)
3. "Welding Design and Fabrication" by K. Mangala Sunder (2015)
4. Welding Symbols on Drawings by E.N. Gregory and A.A. Armstrong, 6th Edition, Woodhead Publishing Limited, 2013.
5. Welding Residual Stress and Its Effects on Fatigue and Fracture edited by Y. Murakami and R. O. Ritchie, 1st Edition, Elsevier Science, 1998.
6. Design of Welded Structures by O. K. Chopra and S. J. Lee, 1st Edition, John Wiley & Sons, 2001.
7. Stress Analysis of Welded Structures by K. F. Chung, 2nd Edition, CRC Press, 2019.

Reference Books:

1. "Structural Welding Code - Steel: Ansi/Aws D1.1-2010" by American Welding Society (2010)
2. "Fatigue Design of Welded Joints and Components: Recommendations of IIW Joint Working Group XIII–XV" edited by M. Gurney and J. Fricke (2016)
3. Welding Metallurgy and Weldability of Stainless Steels by J. C. Lippold and D. J. Kotecki, 1st Edition, John Wiley & Sons, 2005.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc23_me49/preview.

MM26023 **3-0-0 (3)**

Joining and NDT of Ceramics, Polymers and Composites

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the characteristics of ceramics, polymers and composites.
CO-2	Identify materials and methods for ceramics, polymers and composites joining.
CO-3	Distinguish NDT methods for metals, ceramics, polymers and composites.
CO-4	Demonstrate advanced joining and NDT techniques for polymers, ceramics and composites.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Materials: Ceramics, polymers and composites - Introduction, classification, properties, applications.

Introduction to Joining techniques: Necessity for materials (Ceramics, polymers and composites) joining, conventional and non-conventional joining methods for different materials (similar or dissimilar materials joining), its advantages and limitations.

Joining of ceramics: Ceramic-metal/ceramic joining technologies (brazing, metallizing, diffusion bonding etc.); ceramic-polymer joining technologies (adhesive, chemical, brazing etc.), advanced joining techniques (transient liquid phase), active solders, challenges in all these joining processes.

Joining of polymers: Joining methods for polymers – Welding (thermal, mechanical and electromagnetic methods), adhesive bonding (epoxy resins, acrylic acid diesters, cyanoacrylates), riveting, thread systems, press and snap fits etc.

Joining of composites: Different joining techniques of composites (sintering, welding, brazing, soldering), adhesion - cementitious joining, joining using organic and inorganic binders, joining using carbon binders, fastening etc.

Non-destructive Techniques for ceramics: Processing of ceramics: sol gel, co-precipitation, solvent vaporization, porous ceramics, and defects in ceramics. Visual inspection, Ultrasonic NDT, Radiography, Eddy Current, Magnetic Particle NDT, Acoustic Emission NDT, Dye Penetrant NDT, Leak Testing, X-ray tomography, Process compensated resonance testing.

Non-destructive Techniques for composites: Fabrication of composites- Hand layout method, Injection molding, compression molding, resin transfer, pultrution, etc., fracture behaviour of composites, Manufacturing defects and process defects in composites, Modes of failure in composites. Visual testing, Tap test, Ultrasonic testing, Radiography, Shearography testing, Acoustography, Acoustic Emission NDT,

Thermography.

Learning Resources:

Text Books:

1. W. Bolton, Engineering Materials Technology, Butterworth-Heinemann, 2001, 3rd edition.
2. Shigeyuki Somiya, Advance Technical Ceramics, Elsevier, 2003.
3. Deborah D. L. Chung, Composite Materials: Science and Applications, Springer, 210, 2nd Edition.
4. B. Raymond, Seymour and Charles E. Carraher Jr., Marcel Dekkar, Polymer Chemistry, An Introduction, Inc., 1987, 2nd Edition.
5. Sindo Kou, Welding Metallurgy, John Wiley & Sons, 2nd Edition, 2002.
6. Vistap M. Karbhari, Non-Destructive Evaluation (NDE) of Polymer Matrix Composites, Woodhead Publishing, 2013, 1st edition.

Reference Books:

1. S. Somiya, Handbook of Advanced Ceramics, Parts 1 and 2, Academic Press, 2006.
2. Welding Handbook, Vol 2- Welding Processes, AWS, 2004, 9th Edition.
3. Advances in joining of Ceramics, The American Ceramic Society, Wiley Publishers, 2002.
4. William Andrew, Handbook of plastics joining: a practical guide, Inc., 2008, 2nd Edition.
5. K. K. Chawla, Composite Material: Science and Engineering, Springer, 2012 and 3rd edition.
6. David W Richerson, Modern Ceramic Engineering, 2nd edition.

Other Suggested Readings:

1. https://nptel.ac.in/content/storage2/courses/101104010/downloads/Lecture4.pdf
2. https://www.youtube.com/watch?v=7Be7hGvqoAg
3. https://www.twi-global.com/technical-knowledge/faqs/what-is-welding
4. https://www.youtube.com/watch?v=ZMJ7O4vs-Q8

MM26025 **3-0-0 (3)**

Corrosion of Weldments

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the principles of corrosion and corrosion mechanisms.
CO-2	Evaluate the corrosion behaviour of Ferrous and Non-Ferrous Weldments.
CO-3	Explain the corrosion of dissimilar metal weldments and weld corrosion case studies.
CO-4	Suggest suitable techniques for monitoring and testing of weldments.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Principles of Corrosion: Introduction, Corrosion rate expressions, Galvanic and Electrochemical Series, Nernst Expression, Electrochemical aspects- Electrochemical reactions, polarization, passivity, Forms of Corrosion, Preferential HAZ Corrosion, Preferential Weld Metal Corrosion, Mitigation of Preferential Weldment Corrosion, Stress corrosion cracking.

Corrosion of Weldments: Factors influencing and different forms of weld corrosion, Weld Corrosion of Carbon- and Low-Carbon Steel Weldments, Austenitic-, Ferritic-, Martensitic-, Duplex- Stainless Steel Weldments, Non-Ferrous Alloy Weldments, Dissimilar Metal Weldments, Corrosion-Resistant Alloys. Corrosion Monitoring and Testing- Effect of Welding Practice on Weldment Corrosion, Direct testing of coupons, Electrochemical techniques, Testing methods for corrosion of weldments.

Learning Resources:

Text Books:

1. J R Davis (ed), Corrosion of Weldments, ASM International, 2006.
2. M G Fontana, N D Greene, Corrosion Engineering, McGraw Hill, New York, 1967.
3. Nestor Perez, Electrochemistry and Corrosion Science, Kluwer, 2004.

Reference Books:

1. ASM Metal Handbook, Vol 13A- Corrosion, ASM, 2004.
2. Shreir's Corrosion, Four Volumes, Elsevier Science, 2010.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/104/113104082/ (Corrosion I and II, IIT Kanpur).

MM26027 **3-0-0 (3)**

Advanced Experimental Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Demonstrate the principles and operation of different microscopes
CO-2	Analyze images of optical and electron microscopes
CO-3	Use suitable specimen preparation technique for a particular characterization method
CO-4	Explain the operation of dilatometers and interferometers for the characterization of materials
CO-5	Distinguish suitable thermal analysis techniques for different purposes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Stereomicroscopy and its applications, Basic introduction about transmission electron microscope (TEM): Comparison with optical microscope and X-ray diffraction, Properties of electrons, electron beam-specimen interaction.

Design of electron microscope: signal detectors, electron lenses, resolving power, image formation, arrangement for microscopy and diffraction. Specimen preparation and image interpretation: case studies. Field Emission Microscope. Scanning electron microscope (SEM), principles of microprobe analysis. principles of microprobe analysis, Introduction to EBSD.

Thermal analysis of phase transformations: ordinary thermal method, inverse rate curves, differential thermal analysis, derived differential thermal analysis, thermal analysis at high temperatures, thermal analysis with rapid heating and cooling. Thermogravimetric analysis: TG design and experimental concerns. Cahn microbalance operation. Simultaneous thermal analysis. Dilatometry: Single push rod dilatometer, dual push rod dilatometer, calibration. Interferometry: Principles, Michelson interferometer, dilatometric interferometer. Growth of single crystals by zone melting.

Learning Resources:

Text Books:

1. Yang Leng, Materials Characterization Introduction to Microscopic and Spectroscopic Methods, JohnWiley & Sons (Asia) Pte Ltd, 2008
2. C. Suryanarayana and M. Grant Norton, X-Ray Diffraction A Practical Approach, Springer Science+Business Media, LLC, 1998

Reference Books:

1. ASM Handbook: Materials Characterization, ASM International, 2008.
2. V. T. Cherapin and A. K. Mallik: Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.

Other Suggested Readings:

1. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.
2. S.J.B. Reed: Electron Microprobe Analysis, Cambridge University Press, London, 1975.

MM26029 **3-0-0 (3)**

Fatigue and Fracture Mechanics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify deformation and fracture behaviour of materials at room and high temperature
CO-2	Determine theoretical and experimental fracture strength of materials through EPFM, CTOD and J-integral
CO-3	Predict the life of materials under fatigue loading
CO-4	Select metals and alloys for high-temperature applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Concepts of Stress, Strain, Analysis of stresses and strains, principal stresses and strains. Stress / Strain Invariants Theoretical cohesive strength of metals, defects and stress concentration, stress due to crack inside a large plate, Energy balance during propagation of crack, concept of critical stress to propagate crack, Griffith theory

Concept of fracture, steps of fracture, Classification of fracture, Strain energy release rate, Stress intensity factor, Determination of fracture toughness, KIc Fracture toughness, Mechanism of ductile and brittle fracture, Modes of fracture, Common causes of engineering fracture, Fractography, Microscopic fracture modes, Fractographic observation of cleavage/brittle, quasi-cleavage and ductile/dimple fracture

Plasticity at the crack tip, Orowan correction, Strain energy release rate, Irwin's modification, plastic zone shape and size, effect of constraint, plane stress, plane strain, thickness, CTOD, J integral

Fatigue testing and its significance, stress cycles, S-N curve, HCF, LCF, R ratio, Goodman diagram, Paris law, fatigue limit, mechanism of fatigue failure, effect of stress concentration, size, surface condition and environments on fatigue, effect of metallurgical variables on fatigue properties.

Time-dependent deformation - creep, different stages of creep, creep and stress rupture, creep mechanisms.

Failure mechanisms: Embrittlement phenomena, environmental effects, Failures due to faulty heat treatments, Failures in metal forming and welding,

Case studies in failure analysis of welds, Recommendations for Considering Welding Residual Stresses, prevention of failures.

Learning Resources:

Text Books:

1. Mechanical Behavior of Materials, M.A. Meyers
2. and K.K. Chawla, Prentice Hall Inc., 1999.
3. Fracture Mechanics- Fundamentals and Applications, T. L. Anderson, 3rd Edition, CRC Press, 2011.
4. Mechanical Metallurgy, G. E. Dieter, 3rd Edition, McGraw-Hill, 2013.

Reference Books:

1. Deformation and Fracture Mechanics of Engineering Materials, R. W. Hertzberg, 4th Edition, John Wiley & Sons Inc., 2012.
2. Fundamentals of Creep in Metals and Alloys, Michael Kassner, 2nd Edition, Elsevier Science, 2009.
3. Fatigue and Fracture Testing of Weldments, McHencry and Potter (Editors), ASTM STP 1058, Philadelphia, PA, 19103.

MM16041 **3-0-0 (3)**

Strengthening Mechanisms

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify strengthening mechanisms in steels and advanced materials
CO-2	Explain the mechanisms of strengthening in metals and alloys
CO-3	Design thermo-mechanical treatments for high strength steels and alloys
CO-4	Design new materials/heat treatments based on strengthening mechanisms

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	-	3	2	1	
CO-2	-	-	3	2	1	
CO-3	-	-	3	2	1	
CO-4	-	-	3	2	1	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Different methods of strengthening solids; Thermal activation processes; Theories and mechanisms of strain hardening; Solid solution strengthening and Order-disorder transformations; Precipitation hardening; Theories of strengthening and over ageing; Dispersion hardening and theories; Martensitic and bainitic transformations; Special thermo-mechanical treatments for steels; Grain refinement; super plasticity; Fibre-strengthening

Learning Resources:

Text Books:

1. B. Geddes, H. Leon and X. Huang, Strengthening mechanisms, ASM International
2. D. K. Felbeck, Introduction to Strengthening mechanisms, Prentice Hall, London, 1968; Publishedonline by Cambridge University Press: 04 July 2016.
3. D. Hull and D.J. Bacon, Introduction to Dislocations, Butterworth Heinemann, 1984,5th edition.

Reference Books:

1. William D. Callister, Materials Science and Engineering – An introduction, Jr, John Wiley & Sons,Inc. 2004, sixth edition.
2. C.A. Wert and R. M. Thomson, Physics of solids, McGraw-Hill Publishers, 1964

Other Suggested Readings:

1. https://nptel.ac.in/courses/112108150 MIT Open Course Ware, etc.
2. https://www.ias.ac.in/public/Volumes/sadh/003/04/0275-0296.pdf

MM26022 **3-0-0 (3)**

Residual Stresses and Distortion

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the importance of residual stress and distortion control in weldments.
CO-2	Analyze the causes for residual stress and distortion in weld fabrication.
CO-3	Discuss techniques to quantify residual stresses and distortion in welded parts.
CO-4	Recommend methods to reduce the residual stresses and distortion.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	2	-	-	-
CO-2	3	1	2	-	-	-
CO-3	3	3	2	1	-	2
CO-4	3	-	2	1	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Significance of Structural and Residual Stress Analysis, Nature and Causes of Residual Stress, Origin of Thermal Stresses. Residual Stresses due to Mismatch, Residual Stresses from Nonuniform and Nonelastic Strains. Residual Stresses and Distortion caused by Manufacturing Processes: Casting, Welding and Joining, Powder Metal processing, Thermal Forming, Cutting, Gear manufacture, Residual Stress Formation and Distortion in rail steels, Causes of Distortion in Weldments. Residual Stress During Hardening Processes. Residual Stresses in Carburized, Carbonitrided, and Case-Hardened Components, Residual Stresses in Nitriding, Induction Hardening, Hardening by Reheating and Quenching, Metallo-Thermo-Mechanics–Application to Quenching, Effects of Cryogenic Cooling on Residual Stresses, Structure and Substructure. Measurement of Residual Stresses: The X-ray Diffraction Technique, Synchrotron X-ray Diffraction, Neutron Diffraction, Ultrasonics, A Sectioning Technique Using Electric-Resistance Strain Gauges, The Mathar-Soete Hole Drilling Technique, The Rosenthal-Norton Section Technique, The Gunnert Drilling Technique. Residual Stress Distribution Patterns, Effects of specimen size and Weight, Effects of welding sequence, Residual stress in welds made with different welding processes, Effects of residual stresses and distortions on structural strength, fatigue and unstable fracture. Residual Stress and Distortion Control, The Interplay Between Residual Stresses and Distortion, Prevention Versus Remediation, manipulation of residual stresses and distortion, Stress-Relaxation Techniques, Post heat treatment after welding. Calculation/ prediction of residual stress using modern tools, case studies.

Learning Resources:

Text Books:

1. Welding Metallurgy, Sindo Kou, A John Wiley & sons, inc., publication Second Edition (2002)
2. AWS Welding Handbook, VOL-1 - 9th Ed (2001)- Welding Science and Technology
3. Principles of Welding_ Processes, Physics, Chemistry, and Metallurgy, Robert W. Messler Jr - (2004, Wiley-VCH)

4. Practical Residual Stress Measurement Methods, Ed. by Gary S. Schajer, A John Wiley & sons, inc., publication 2013
5. Handbook of Residual Stress and Deformation of Steel, Ed. by G. Totten, M. Howes, T. Inoue, ASM International, 2002

Reference Books:

1. The use of a portable X-ray unit for measuring residual stresses in aluminum, titanium, and steel alloys. In Advances in X-ray analysis. D. A. Boldstad and W. E. Quist, eds. New York: Plenum Press. 1965.
2. Welding Deformation and Residual Stress Prevention, Y. Ueda, H. Murakawa, N. Ma, Elsevier, 2012
3. Structural and Residual Stress Analysis by Non-destructive Methods Evaluation Application and Assessment, V. Hauk, Elsevier, 1997
4. Computational Welding Mechanics, J. A. Goldak and A. Mehdi, Springer, NY, 2005.

MM26024 **3-0-0 (3)**

Welding Application Technology

Pre-Requisites: None

Course Outcomes:

CO-1	Evaluate the impact of welding procedures and specifications on weld quality.
CO-2	Develop and implement welding fabrication plans.
CO-3	Apply confirming documentation for weld inspection.
CO-4	Apply preventive and corrective measures for welding defects and distortions.
CO-5	Demonstrate knowledge of relevant standards and codes for weld fabrication.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	2	2	-	1
CO-3	3	-	2	2	-	1
CO-4	3	-	-	2	-	1
CO-5	3	-	-	2	-	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Quality Control of Welding Construction: Importance of Quality Control in Welding Fabrication, Global Trends in Quality Management Systems (QC and QA), Design Quality and Manufacturing Quality

Welding Codes and Standards: Overview of Welding Codes and Standards, AWS D1.1 and ISO 3834 standards, Welding Procedure Specifications (WPS) and Welding Qualification

Welding Fabrication Planning: Drafting and Qualification of Welding Procedure Specification (WPS), Estimation of Welding Work Volume, Planning of Schedule, Welding Equipment, Welding Personnel, Testing and Inspection and

Welding Costs: Materials, equipment, personal cost consideration.

Heat Treatment Before and After Welding: Introduction to Heat Treatment, Pre-Welding Heat Treatment, Post Welding Heat Treatment, Heat Treatment Methods, Heat Treatment Standards and Codes

Prevention and Correction of Weld Distortion: Introduction to Weld Distortion, Causes of Weld Distortion, Prevention of Weld Distortion, Correction Methods of Weld Distortion

Welding Performance Control: Introduction to Welding Performance Control, Types of Welding Performance Control, Welding Process Variables and their Effect on Welding Performance, Monitoring and Controlling Welding Performance, Testing and Inspection of Welds for Performance (API 577)

Repair Welding: Definition and importance of repair welding, condition assessment & feasibility of repair welding, repair welding procedure: preparation, removal of defects, flaw excavation, cleaning and

determination of the size of flaw, repair thin-gauge materials and plastics and composites, welding repairs of corrosion damage, welding and other metal deposition methods for dimensional restoration.

Safety and Health: Protection from Heat, Light, Flying Objects and Fume, Prevention of Electric Shock, Prevention of Fire and Explosion, Safety and Health Corresponding to Work Environments, Safety in Welding Robot, Safety in Laser Welding and Cutting

Learning Resources:

Text Books:

1.J.G. Lippold and D.J. Kotecki, "Metallurgy and Welding for Engineers", 2nd edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2005.

2. J.C. Lippold and D.J. Kotecki, "Welding Metallurgy and Weldability of Stainless Steels", John Wiley & Sons, Inc., Hoboken, New Jersey, 2005.

3. Sindo Kou, "Welding Metallurgy", 2nd edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2003.

4. J.F. Lancaster, "Practical Welding Metallurgy", 2nd edition, Woodhead Publishing Limited, Cambridge, England, 2005.

Reference Books:

1. Metals Handbook Desk Edition, American Society for Metals, USA, 1998.
2. 1.ASM Handbook, Volume 6A: Welding Fundamentals and Processes, edited by T. Lienert, 10th edition, ASM International, Materials Park, Ohio, 2011.

Other Suggested Readings:

1. https://www.twi-global.com/technical-knowledge/faqs/faq-i-have-to-weld-a-non-ferrous- metal-what-does-non-ferrous-mean-and-what-thing
2. https://onlinecourses.nptel.ac.in/noc23_me49/preview.

MM26026 **3-0-0 (3)**

Statistics, Quality and Reliability

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe life-cycle cost analysis, optimal maintenance and repair strategies.
CO-2	Evaluate structural components reliability using simulation and sampling techniques.
CO-3	Perform simple SQC calculations applied to real world applications.
CO-4	Apply time-independent reliability formulation for failure probability of structure.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	2	3	-	-	1
CO-2	-	2	3	-	-	1
CO-3	-	2	3	-	-	1
CO-4	-	2	3	-	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Probability and Random Variable: Concepts of probability – Random variables – Baye's Theorem – Standard Probability Distributions – Binomial, Poisson, Normal, Geometric, Exponential distributions – Correlation and Regression.

Statistical Quality Control: Statistical basis for control charts – control limits – control charts and types – control charts for variables, defective and defects – introduction to six sigma – inspections by sampling – OC curves – acceptance sampling plans.

Quality: Basics of quality – Quality philosophy – quality control – quality assurance – design for quality management system – Quality certification and accreditation schemes – total quality management and Taguchi's method – quality standards and procedures

Reliability: Basic concepts of reliability – Reliability Vs Quality – Hazard and failure rate analysis – mean time between failures (MTBF) – mean time to failure (MTTF) –Reliability of systems – Series system, Parallel system, Series-Parallel system.

Design of experiments (DoE): basic principles, full factorial, response surface methodology**.**

Learning Resources:

Text Books:

1. Introduction to Statistical Quality Control, D. C. Montgomery, John Wiley & Sons, 2009, 6ed.
2. Fundamentals of Mathematical Statistics, S. C. Gupta and V. K. Kapoor, S. Chand, 2000, 10ed.
3. Reliability Engineering: Theory and Practice, A. Birolini, Springer, 2010, 6ed

Reference Books:

1. The Six Sigma Handbook, Thomas Pyzdek, McGraw-Hill, 2000.
2. An introduction to Reliability and Maintainability engineering, C. E. Ebeling, 2009, Waveland, 2ed.
3. Total Quality Management, J. S. Oakland, Butterworth–Heinemann Ltd., 2003, 3ed..

Other Suggested Readings:

1. Statistical Quality Control, R.S. Leavenworth, E. L. Grant, Tata McGraw –Hill Education, 2000, 7ed.
2. Non-destructive Evaluation: A Tool in Design, Manufacturing and Service, Don E. Bray and Roderic K. Stanley, CRC Press, 1996.

MM26028 **3-0-0 (3)**

Mechanical Behavior of Weldments

Pre-Requisites: **None**

Course Outcomes:

CO-1	Correlate welding parameters with mechanical properties of welding
CO-2	Analyze failure mechanisms in welding
CO-3	Evaluate of fracture risk in welding

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	2	3	-	-	-
CO-2	-	2	3	-	-	-
CO-3	-	2	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Failure mechanisms, Mixed mode and fatigue failures, Embrittlement phenomena, environmental effects, Failures due to faulty heat treatments, Failures in metal forming and welding

Fatigue, HCF, LCF, Paris law, Fatigue strength, Fatigue failure of the principal welded joints, Factors in welded joint endurance

Evaluation of fracture risks, ductile-brittle transition temperature, elastic linear field and elasto-plastic field fracture, fracture risks in welded joints, Heterogenities of the weld bead, Conditions of specimen craking, Various methods of toughness evaluation.

Learning Resources:

Text Books:

1. George E. Dieter, Mechanical Metallurgy, McGraw Hill, New York, 3rd Edition, 1986. (ISBN 0-07-016853-8) TA405.D53
2. Régis Blondeau (editor), Metallurgy and Mechanics of Welding, Wiley Publishing company 2008, (ISBN: 978-1-118-62374-9)
3. Norman E. Dowling, Mechanical Behavior of Materials, Prentice-Hall, Upper Saddle River, New Jersey, 2nd Edition, 1999. (ISBN0-13-905720-X)

Reference Books:

1. Thomas H. Courtney, Mechanical Behavior of Materials, McGraw Hill, New York, 2nd Edition, 2000. (ISBN0-07-028594-2) TA405.C859
2. William F. Hosford, Mechanical Behavior of Materials, Cambridge University Press 2005
3. MA Meyers and K Chawla, Mechanical Behavior of Materials, Prentice Hall

4. David Broek, Elementary Engineering Fracture Mechanics, Martinus Nijhoff Publishers, Hingham, Massachusetts, 3rd Edition, 1984. (ISBN 90-247-2656-5)
5. Richard W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, John Wiley & Sons, New York, 3rd Edition, 1989. (ISBN 0-471-63589-8) TA417.6H46

MM26030 **3-0-0 (3)**

Computational Methods for Welding and Joining

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the fundamentals of heat transfer, fluid flow, and metallurgical transformations in welding.
CO-2	Apply numerical methods for modeling welding processes.
CO-3	Use simulation software used in welding engineering.
CO-4	Apply modeling and simulation techniques to solve real-world welding problems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	2	2	–	–
CO-2	3	2	2	2	–	–
CO-3	2	2	2	3	–	–
CO-4	2	–	2	3	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Overview of welding techniques, principles of heat transfer applied to welding and joining processes, thermal cycles in welding, analytical solutions for temperature distribution; fluid flow fundamentals, weld pool dynamics, Marangoni effect and buoyancy forces, mathematical modelling of weld pool convection, metallurgical aspects of welding, phase prediction using CALPHAD approaches; applications of numerical methods to welding: FEM, FDM and CFD, simulation software tools: ANSYS, ABAQUS; machine learning in welding; residual stresses and its prediction, case studies.

Learning Resources:

Text Books:

1. Robert W. Messler Jr., Principles of Welding: Processes, Physics, Chemistry, and Metallurgy Wiley-VCH, 1999.
2. G. Ravichandran, Finite Element Analysis of Weld Thermal Cycles Using ANSYS, CRC Press, 2020

Reference Books:

1. H. Cerjak, H. K. D. H. Bhadeshia Eds., Mathematical Modelling of Weld Phenomena, CRC Press, 2002
2. Lars-Erik Lindgren, Computational Welding Mechanics, Woodhead Publishing Series in Welding and Other Joining Technologies, 2014

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc21_me36/preview
2. https://archive.nptel.ac.in/courses/113/106/113106067/

EC16062 **3-0-0 (3)**

Signal and Image Processing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss principles, algorithms and applications of digital signal processing (DSP).
CO-2	Explain image acquisition and processing techniques.
CO-3	Discuss image enhancement in both spatial and frequency domains.
CO-4	Use image compression techniques for storage and transmission purpose.
CO-5	Apply image segmentation / morphological operations for object and boundary detection.
CO-6	Select Image processing/DSP techniques for industrial and NDE applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	3	2	2	–	–
CO-2	-	3	2	2	–	–
CO-3	-	3	2	2	–	–
CO-4	-	3	2	2	–	–
CO-5	-	3	3	3	-	-
CO-6	-	3	3	3	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamentals of Digital Signal Processing: Sampling and aliasing, Signal reconstruction, Signal conversion system, Characterization and classification of signals and systems, Z-Transform, inverse Z-Transform, Properties of The Z Transform, Convolution, Correlation, Discrete Fourier transform (DFT), Properties of the DFT.

Digital Image Fundamentals: Overview of Image Processing, Digital Image Representation, Types of Images, Digital Image Processing Operations, Fundamental Steps in Image Processing, Image processing Applications, Digital Imaging System, Elements of Visual perception. Image sensing and Acquisition, Sampling and Quantization, Relationship between pixels.

Image Enhancement: Some basic gray level transformations, Histogram processing, Smoothing and Sharpening spatial filters, Image Enhancement in Frequency Domain: Smoothing and sharpening frequency domain filters, Image Restoration Techniques.

Image compression: Image compression models, Loss-less and Lossy compression, Applications Morphological Image Processing: Dilation and erosion, Opening and closing, some basic morphological algorithms.

Image Segmentation: Detection of discontinuities, Edge and boundary detection, Thresholding, Region based segmentation.

Case Study: Image Processing for Materials Characterization, detection of various defects in materials, Image processing and DSP for industrial and NDE applications.

Learning Resources:

Text Books:

1. Digital Signal Processing, Principles Algorithms and Applications, Third edition; John G,Proakis and Dimitris G Manolakis (Prentice Hall).
2. S. Salivahanan, A. Vallavaraj, and C. Gnanapriya, Digital Signal Processing Tata McGraw Hill Publication 1st Edition (2010).
3. R. C.Gonzalez, R.E.Woods," Digital Image processing", Pearson edition, Inc3/e,2008.
4. Jayaraman, Subramania, S. Esakkirajan, and T. Veerakumar. Digital image processing. Vol. 7014. New Delhi: Tata McGraw Hill Education, 2009.

Reference Books:

1. J.C. Russ," The Image Processing Handbook", (5/e), CRC, 2006
2. R.C.Gonzalez & R.E. Woods; "Digital Image Processing with MATLAB", Prentice Hall, 2003
3. Anand Kumar, Digital Signal Processing, PHI Learning Pvt. Ltd. 2013.
4. S. Sridhar, Digital Image Processing, Oxford University Press, Second Edition, 2012.
5. A.K.Jain," Fundamentals of Digital Image Processing", PHI,1995.

MM16022 **3-0-0 (3)**

Additive Manufacturing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the basic concepts and importance of additive manufacturing
CO-2	Describe the principles, processes and advantages of additive manufacturing systems
CO-3	Apply the knowledge of additive manufacturing for various real-life applications
CO-4	Suggest mitigation techniques for additive manufacturing defects

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	-
CO-2	3	-	-	2	-	-
CO-3	3	-	-	2	-	-
CO-4	3	-	3	2	-	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview, basic principles and advantages of additive manufacturing, procedure of product development in additive manufacturing, classification of additive manufacturing processes, materials used in additive manufacturing, challenges in additive manufacturing.

Generic AM process: CAD, conversion of STL, transfer to AM machine and STL file manipulation, machine setup, build, removal, distinction between AM and CNC machining, reverse engineering Additive Manufacturing Processes: Z-Corporation 3D-printing, Stereolithography apparatus (SLA), Fused deposition modeling (FDM), Laminated Object Manufacturing (LOM), Ultrasonic consolidation, Material Jetting, Binder jetting

Powder bed fusion processes: Selective laser sintering (SLS), Laser engineered net shaping (LENS), Selective laser melting (SLM), Electron beam melting (EBM), materials, powder fusion mechanisms (Solid-state sintering, chemically induced sintering, liquid phase sintering, Full melting), powder handling challenges, powder recycling, defects

Direct energy deposition processes: DED process description, powder feeding, wire feeding, laser and electron-based deposition processes

Post-Processing in Additive Manufacturing: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques, brief information on characterization techniques used in additive manufacturing, applications of additive manufacturing in rapid prototyping, rapid manufacturing, rapid tooling, repairing and coating.

Future scope in Additive Manufacturing: Evaluation of additive manufactured structures/ components, scope of AM in various fields. Its importance and applications.

Learning Resources:

Text Books:

1. C.K. Chua, K.F. Leong, C.S. Lim: Rapid prototyping- Principles and applications, 3rd Ed., World Scientific Publishers, 2010.
2. Gibson, I, Rosen D W., and Stucker B., Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010
3. Chee Kai Chua, Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications: Fourth Edition of Rapid Prototyping, World Scientific Publishers, 2014
4. A.Gebhardt: Rapid prototyping, Hanser Gardener Publications, 2003.
5. L.W. Liou, F.W. Liou: Rapid Prototyping and Engineering applications: A toolbox for prototype development, CRC Press, 2007.
6. A.K. Kamrani, E.A. Nasr: Rapid Prototyping- Theory and Practice, Springer, 2006.
7. P.D. Hilton, P.F. Jacobs: Rapid Tooling- Technologies and Industrial Applications, CRC Press, 2000.
8. Ian Gibson, David W Rosen, Brent Stucker: Additive Manufacturing Technologies- Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010
9. D.T. Pham, S.S. Dimov: Rapid Manufacturing- The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer, 2001.C.K. Chua, K.F. Leong, C.S. Lim: Rapid prototyping- Principles and applications, 3rd Ed., World Scientific Publishers, 2010.

Reference Books:

1. Additive Manufacturing Processes, Editor: David L. Bourell, William Frazier, Howard Kuhn, and Mohsen Seifi, ASM Hand Book, Volume 24, ASM International, 2020Title of the Text Book, Author(s), Publisher, Year and Edition

Other Suggested Readings:

1. https://additivemanufacturing.com/basics/
2. https://www.additivemanufacturing.media/

MM16038 **3-0-0 (3)**

Design and Selection of Advanced Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss materials selection methodologies
CO-2	Apply statistics in materials selection
CO-3	Analyze the influence of composition, heat treatment and microstructure on the properties of engineering materials
CO-4	Select suitable materials for structural and functional applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	-	1	2	-	-
CO-2	-	-	1	2	-	-
CO-3	-	-	3	3	2	-
CO-4	-	-	3	3	2	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Revision of engineering materials: Classification of materials- metals and alloys, ceramics, polymers and composites, Importance of materials selection and metallurgical design, Properties and applications of plain carbon steels and common non-ferrous alloys.

Criteria for selection of materials: Ashby charts for materials selection, application of statistics in materials,specification of steels, Composition, heat treatment, microstructure and properties of ferrous and non- ferrous alloys, ceramics, and polymers for light and heavy structural, corrosion-resistant, high temperature, low-temperature, and cryogenic, wear-resistant, magnetic, electrical and electronic applications, pressure vessels and boilers, bearings, tools, medical implants and prostheses application, Composites, shape memory alloys, metallic glasses, nanocrystalline materials.

Learning Resources:

Text Books:

1. M.F. Ashby, Engineering Materials, 4th Edition, Elsevier, 2005.
2. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 2005.
3. Pat L. Mangonon, The Principles of Materials Selection and Design, Prentice Hall International, Inc.1999.

Reference Books:

1. ASM Metals Handbook, Vol.20: Materials Selection and Design, ASM, 1997.

Other Suggested Readings:

1. https://www.youtube.com/watch?v=9RQkvcsRzbo

MM16024 **3-0-0 (3)**

Surface Engineering and Coating Technologies

Pre-Requisites: None

Course Outcomes:

CO-1	Differentiate diffusion and overlay coatings
CO-2	Explain the principles of thermo-chemical surface engineering techniques and thin film coatings
CO-3	Evaluate thermal modification processes applicable to surface modification of industrial components
CO-4	Evaluate the performance of coatings

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Importance and need of surface engineering, Past, present and future status of surface engineering, Classification of surface engineering processes. Coating characteristics: Coating thickness, continuity, hardness, adhesion, porosity, bond strength.

Overlay coatings: Process fundamentals, advantages, limitations, and applications of (a) Thermally sprayed coatings, b) Electrochemical coatings-; (c) Micro arc oxidation- (d) Electro-spark coating-process.

Diffusion coatings: Process fundamentals, advantages, limitations and applications of; Plasma processes'

Thermal modification processes: Different types of lasers and their applications, Laser-assisted surface modification processes-Laser surface cleaning, Laser surface hardening, Laser surface cladding,Laser surface alloying; Flame hardening and Induction hardening.

Thin film coating technology: Chemical vapour deposition (CVD), Physical vapour deposition (PVD), Electron beam evaporation, Magnetron sputtering; Diamond-like carbon coating technology; Sol-gel coating technologies;

Evaluation of coatings: Thickness, bond strength and porosity measurement, Hardness, wear and corrosion resistance. Case Studies

Learning Resources:

Text Books:

1. Tadeusz Burakowski and Tadeusz Wierzchon, Surface Engineering of Metals: Principles, Equipment, Technologies, CRC Press LLC, 1999
2. K. G. Budinski, Surface Engineering for Wear Resistance, Prentice-Hall, New Jersey, 1998.
3. J. R. Davis, Surface Engineering for Corrosion and Wear resistance, ASM International, 2001
4. Howard E. Boyer, Case Hardening of Steel, ASM International, Metals Park, OH 44073.
5. ASM Hand Book, Surface Engineering, Volume 5, ASM Metals Park. Ohio. USA. 1994

MM16040 **3-0-0 (3)**

Metallurgy of Steels

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the strengthening mechanisms to enhance the properties of steels
CO-2	Differentiate between the properties of various special steels and their applications
CO-3	Evaluate the principles of micro-alloying and thermomechanical processing of steels
CO-4	Analyze the problems associated with heat treatment of tool steels and ultrafine grained steels
CO-5	Describe the challenges associated with developing nuclear grade steels

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	-	2	2	2	-
CO-2	1	-	3	2	-	-
CO-3	-	-	3	2	-	-
CO-4	1	-	3	2	2	-
CO-5	1	-	-	3	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

General Introduction: Properties and importance of various steels.

Review of strengthening mechanisms applicable to steels: Grain refinement, solid solution, precipitation, dispersion of second phases, martensite, twinning, work hardening.

Development of various steels: Principles of alloying, heat treatment and thermomechanical processingin steels. Production of dual phase steels, TRIP steels, TWIP steels; bainitic steels, IF steels, HSLA &advanced high strength low alloy steels, maraging steels, stainless steels, power plant steels, nuclear steels, high nitrogen stainless steels, tool steels, ultrafine grained steels. Non-equilibrium processing of steels.

Structure – property correlations in various steels: Applications – structural, consumer, automotive, Nuclear and aerospace industries.

Learning Resources:

Text Books:

1. W.C. Leslie, Physical Metallurgy of Steels, Tech Books, 1991. .
2. F.B. Pickering, Physical Metallurgy and Design of Steels, Applied Science Publishers, 1978.
3. H.K.D.H. Bhadeshia, Bainite in Steels-Transformations, Microstructure and Properties, CUP, 2001.

Reference Books:

1. George Adam Roberts, Richard Kennedy, G. Krauss, Tool Steels, 5th Ed., ASM, 1998.
2. Albert M. Hall, Introduction to Today's Ultrahigh-strength Structural Steels, ASTM Special TechnicalPublication, 1973.

Other Suggested Readings:

1. R.F. Decker, Source Book on Maraging Steels, ASM, 1979.