OLD

Subject Code : MET 811
Title of the course : DESIGN OF EXPERIMENTS

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:
After successful completion of course, the students should be able to:

CO1: Understand the basic concepts of optimization.
CO2: Understand the basic concepts of experimentation analysis like selection of random variables.
CO3: Construct mathematical model for random phenomena like Null Hypothesis and Alternative Hypothesis.
CO4: Obtain engineering solutions based on statistical analysis like Factorial Design and Taguchi Method .
CO5: Analyze the variance like one-way ANOVA, two ways ANOVA, numerical on ANOVA, Z-test and T test

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO 9	PO10	PO11	PO12
CO1	S	S	S	S	M	--	--	--	--	M	W	-
CO2	S	S	S	S	M	--	--	--	--	M	W	-
CO3	S	S	S	S	M	--	--	--	S	M	M	-
CO4	S	S	S	S	M	--	--	--	--	M	M	-
CO5	S	S	S	S	M				S			S

Theory:

SECTION I

INTRODUCTION (8 Hrs)
Brief introduction of optimization techniques, Strategy of experimentation, Basic principles of Design, Terminology used in Design of Experiment, Guidelines for designing experiments, Basic statistical concepts: Types of Data, Graphical representation of Data, Measures of Central Tendency and Dispersion, Skewness.

SIMPLE COMPARATIVE EXPERIMENTS (8 Hrs)
Sampling and sampling Distribution, Test of significance for single mean and for difference of means of two samples, Inferences about the Differences in means: randomized designs, Inferences about the Differences in means: Paired comparison Designs, Inferences about the Variances of Normal Distributions. Test of significance based on t, F and Chi square distribution.

FITTING REGRESSION MODELS (8 Hrs)

Introduction, Linear regression models, Estimate of parameters in linear regression models, The method of least square, Hypothesis testing : Null Hypothesis, Alternative Hypothesis, Prediction of new response observations, Testing for lack of fit.

SECTION II

FACTORIAL DESIGN (8 Hrs)

Basic definition and principles, Advantages of factorials, Types of factorial design: Full factor factorial design and fraction factorial design, Design Matrix, Development of mathematical model, Regression model diagnostics.

TAGUCHI METHOD (8 Hrs)

Introduction, Concept design, Parameter design, Tolerance design, Orthogonal array experiments Taguchi quality loss function, Signal-to Noise ratio, Quality characteristics, Parameter optimization experiment, Parameter design case study.

ANALYSIS OF VARIANCE (ANOVA) (8 Hrs)

Introduction, One way ANOVA process, Two way ANOVA process, Degrees of freedom, Case studies on Factorial design, Taguchi Method and ANOVA.

Books Recommended

1. Design and Analysis of Experiments, Douglas C Montgomery, John Wiley
2. Statistical Design and Analysis of Experiments, John P.W.M., Macmillan,.
3. Introduction to Linear Regression Analysis, Montgomery D.C., Runger G. C.,
4. Introduction to Quality Engineering, Taguchi, G., Asian Productivity Organisation, UNIPUB, White Plains, New York
5. Statistical Methods for Engineering and Sciences, Taneja HC, IK International Publishing house Pvt Ltd.
6. Statistical Analysis for Engineers And Scientists, J. Wesley Barnes, McGraw Hill Inc.

Subject Code : MET 816

Title of the course : CONVENTIONAL WELDING PROCESSES

L	T	P	Credits	Weekly Load
3	1	2	5	5

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Learn, understand and apply knowledge about occupational health and safety during welding operations.

CO2: Gain fundamental knowledge about various conventional welding processes.

CO3: Select suitable welding process along with parameter selection for a particular operation.

CO4: Compare different welding processes in terms of working principle, advantages, and limitations along with their main area of applications.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S											
CO2			S									
CO3		S	S	S								
CO4		S	S		S		S					S

Theory:

UNIT- I

Introduction **4**

Welding– Definition, industrial importance, applications; advantages of welding over other fabrication processes; classification of welding and allied processes.

Welding Safety and Hazards **4**

Hazards associated with gas and arc welding processes, protection against electric shock, arc radiations, fumes and dust, compressed gases, fire and explosions.

Oxy Acetylene Welding (OAW) **4**

Basic principle and equipment used; types of flames, their characteristics and applications; introduction to gas cutting.

Fundamentals of Arc Welding & Power Sources **8**

Arc- arc characteristics- arc physics, arc plasma, arc structure, arc stability, arc efficiency; brief introduction to bead geometry and melting rate, mode of metal transfer- short circuit, globular and spray mode of transfer, various factors and forces affecting metal transfer; welding power sources- introduction to transformers, rectifiers and inverters; power source characteristics- static and dynamic volt-ampere characteristics, duty cycle; arc blow- causes and its control.

Shielded Metal Arc Welding (SMAW) **4**

Basic principle and equipment used; welding parameters and their effect on weld bead characteristics; covered electrodes- functions of electrode coating, types of coating and their characteristics, classification and coding of covered electrodes as per IS & AWS standards; advantages, limitations and applications.

UNIT II

Gas Metal Arc Welding (GMAW) **4**

Basic principle and equipment used; welding parameters and their effect on weld bead characteristics; shielding gases- types, characteristics and applications; pulsed MIG welding; introduction to flux cored arc welding; advantages, limitations and applications.

Gas Tungsten Arc Welding (GTAW) **6**

Basic principle and equipment used; arc initiation method and arc stability; types of tungsten electrode and their applications; Purging techniques, shielding gases and their applications; effect of polarity on weld characteristics, requirement for DC suppresser unit; pulse TIG welding; electrode contamination; advantages, limitations and applications.

Submerged Arc Welding (SAW) **6**

Basic principle and equipment used; welding parameters and their effect on weld bead characteristics; SAW fluxes- classification and their characteristics; coding of flux wire combination as per BIS and AWS; introduction to multi-wire and multi power systems, strip cladding, narrow gap welding; advantages, limitations and applications.

Plasma Arc Welding (PAW) **4**

Basic principle and equipment used; plasma forming and shielding gases; transferred and non-transferred arc modes; micro-plasma welding; advantages, limitations and applications.

Resistance Welding **4**

Basic principle; Brief introduction to spot, seam, projection and flash butt welding; welding variables; heat shrinkage, heat balance; process capabilities and applications. Stud welding; Basic principle & applications.

Books recommended

1. S.V.Nadkarni, "Modern Arc Welding Technology", Oxford & IBH.
2. H.B.Cary, "Modern Arc Welding Technology", Englewood Cliffs, Prentice Hall.
3. Leonard P Connor, Welding Hand book, Volume I-III, AWS.
4. Metals Hand book , Volume 6, American Society of Metals.
5. Dave Smith, "Welding skills and technology", McGraw Hill.
6. R.Little, "Welding Technology, TMH.

Subject Code : MET 817

Title of the course : INSPECTION AND TESTING OF WELDS

L	T	P	Credits	Weekly Load
3	1	2	5	5

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Understand the importance of quality assurance & control in welded joints.

CO2: Learn, identify, interpret and apply knowledge about various weld defects along with remedial measures to overcome these defects.

CO3: Learn to plan, prepare, conduct and analyze about service weldability tests including different destructive tests performed on welded joints

CO4: Learn to plan, prepare, conduct and analyze the results obtained from various non-destructive tests performed on welds.

CO5: Appraise, evaluate, report, predict and recommend/conclude on the overall strength characteristics of welds.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S		S						S			S
CO2	S	S										
CO3	S	S	S		S							
CO4	S			S								
CO5			S	S	S	S			S			S

Theory:

SECTION I

INTRODUCTION **8**

Quality-Weld quality, quality assurance concept in welding; brief introduction to procedure and welder's qualification, requirement of destructive and non-destructive testing for quality control of welds.

WELDING DEFECTS **8**

Classification of weld defects, arc welding defects: surface defects like cracks, incorrect weld profile, distortion, undercuts, overlaps, dimensional defects, underfill, burn through, spatter, as well as sub-surface defects; sub-surface defects like lack of fusion, cracks, lack of penetration, blowholes, porosity, inclusions etc.

DESTRUCTIVE TESTING (DT) IN WELDING **8**

Service weldability tests:

Tension tests: All weld metal test, longitudinal butt weld test, transverse butt weld test

Bend tests: Free bend test, guided bend test, controlled bend test

Impact testing: Charpy and Izod tests

Hardness tests: Brinell, Vickers, Rockwell hardness tests, micro-hardness test

Fatigue test- Fatigue failure, test procedure, recording of fatigue data, S-N diagram, Goodman diagram.

SECTION II

NON DESTRUCTIVE TESTING (NDT) IN WELDING

Visual inspection of welds

Liquid penetrant testing: dye penetrant testing – procedure, penetrant testing materials, penetrant testing method, sensitivity; applications and limitations

Magnetic Particle Testing (MPT): definition and principle, longitudinal vs. circular magnetization, different magnetizing techniques, procedure, equipment sensitivity and limitation.

Eddy current: principle, instrument techniques, sensitivity, application and limitations;

Radiography Testing (RT): Production and properties of X-rays, □-ray sources; Basic principle and procedure; radiographic imaging- sensitivity, film speed, exposure time, film density, image quality indicators; inspection techniques- single and double wall imaging techniques; applications and limitations; real time radiography; safety against radiation hazards

Ultrasonic testing: principle of UT, basic properties of sound beam, ultrasonic transducers, inspection methods, technique for normal beam inspection, weld testing using angular probes, modes of display, immersion testing, advantage, limitations

Acoustic emission testing: principles of AET. **24**

Books recommended:

1. *Metals Hand book* (Mechanical Testing), Volume VIII, American Society of Metals.
2. S.V.Nadkarni, *Modern Arc Welding Technology*, Oxford & IBH.

3. Leonard P Connor, *AWS Welding Hand book*, Volume I, American Welding Society.

Subject Code : MET 818

Title of the course : PHYSICAL METALLURGY

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Understand different concepts related to crystallography of metallic materials.

CO2: Gain knowledge about Iron Carbon equilibrium, TTT and CCT diagrams.

CO3: Learn and understand the use of various heat treatment processes.

CO4: Gain knowledge about various types of corrosion along with different remedial measures for its control.

CO5: Have an overview of various materials for engineering applications.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2	S											
CO3		S	S								S	S
CO4	S											
CO5									S			

Theory:

SECTION I

Crystallography **6**

Crystallography - space lattice - unit cell - classification of space lattices by crystal system - packing factor - indexing of crystal planes and directions in cubic and hexagonal system - defects in crystals - dislocation concepts - slip and twin crystal orientation.

Strengthening Mechanisms **6**

Work hardening, solid solution strengthening, strengthens by heat treatment

Nucleation and Growth **6**

Concept of free energy, Nucleation and crystal growth during solidification, Homogeneous nucleation, critical size of the nucleus, Ingot Structure, Coring and segregation

Phase transformations **6**

Basics of binary and ternary phase diagram, diffusion kinetics. Important features of pearlitic, bainitic and martensitic transformations,

SECTION II

Iron Iron-Carbide Equilibrium Diagram

Introduction to iron-iron carbide diagram, TTT and CCT diagrams. **4**

Heat treatment

Annealing, normalizing, hardening and tempering, stress relieving ***6***

Case hardening **4**

Carburizing, nitriding, cyaniding, flame hardening and induction hardening

Corrosion

Introduction, various types of corrosion, and respective possible causes, Methods of preventing corrosion **4**

Overview of Metallic Materials **6**

Plain carbon steels, low alloy and Q-T steels, dual phase steels, HSLA steels, Hadfield steel, stainless steels, tool steels, ultra-high strength steels- maraging steels.

Books recommended:

1. S.H.Avner, “Introduction to Physical Metallurgy”, McGraw Hill.
2. V.Raghavan, “Physical Metallurgy (Principles and Practice)”, Prentice Hall.
3. D.S. Clarke and W.R.Varney, “Physical Metallurgy for Engineers”, CBS.
4. T.V.Rajan, C.P.Sharma and Ashok Sharma, “Heat Treatment – Principles and Techniques”, Prentice Hall of India.

5. Y.S Laktin, “Engineering Physical Metallurgy and Heat treatment”, MIR publishers.
6. Metals Hand book , Volume I-VI, American Society of Metals.

Subject Code : MET 815 A
Title of the course : Finite Element Methods

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Understand Strain-displacement and Stress-strain relations with and without the temperature effect.

CO2: Explain various numerical methods which can be applied to mechanical problems.

CO3: Discretize the continuum domain into finite element mesh using various types of elements.

CO4: Apply the finite element methods to solve static, scalar field and dynamic problems.

CO5: Formulate the computer implementation of the finite element methods.

Pre-requisite knowledge:

CO/PO Mapping: (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S											
CO2	M	S										
CO3				M								
CO4				S							M	
CO5				S					W			M

Theory:

SECTION-I

Introduction & Fundamental Concepts 12

Historical Background, Stresses and equilibrium, Boundary Conditions, Strain-Displacement Relations, Stress-Strain Relations, Temperature Effects, Vectors and Matrices.

Different Methods and Applications

Classification of Differential Equations, Rayleigh-Ritz Method, Galerkin’s Method, Point Collocation Method, Least Square Method, Weighted Residual Method,Variational Formulation.

1-D FE Modeling 12

Finite Element Modeling, Coordinates and Shape Functions, Generalized Coordinates, Natural Coordinates in 1D, 2D and 3D, Coordinate Transformation, Assembly of Global Stiffness matrix and Load vector, Properties of Stiffness Matrix, Treatment of Boundary Conditions and Temperature Effects. Truss and Beam Elements. Simple problems.

2-D FE Modeling

Finite Element Modeling, Constant Strain Triangle (CST).

SECTION-II

2-D FE Modeling 12

The Four Node Quadrilateral, Numerical Integration, Higher Order Elements; Nine Node Quadrilateral, Eight Node Quadrilaterals, Six Node Triangle.

Truss

Introduction, Plane Trusses, Assembly of Global Stiffness Matrix and load vector, displacement.

Higher-Order Elements

Plate Bending, C^0 and C^1 Elements, Non-conforming Elements and Patch Test.

Scalar Field Problems 12

Introduction, Steady-state heat transfer, Potential Flow, Fluid Flow in Ducts.

Dynamic Considerations

Element Mass Matrices, Evaluation of Eigen Values and Eigen Vectors. (Introduction)

Computer Implementation

Introduction; Computer Program Organization for Calculation of System Matrices.

Recommended Books:

Title	***Author(s)***	***Publisher***
Introduction to Finite Elements in Engineering	Chandrupatla and Belegundu	PHI
Finite Element Procedures	K.J. Bathe	PHI
An Introduction to Finite Element Method	J. N. Reddy	TMH
The Finite Element Methods for Engineers	Huebner	John Wiley
The Finite Element Method	O.C. Zienkiewicz	TMH
Finite Element Analysis	Buchanan	McGraw Hill

Subject Code : MET 815E

Title of the course : PHYSICS OF WELDING

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Learn and understand different physical properties of fluids at elevated temperatures.

CO2: Gain knowledge about the basic concepts of electricity and magnetism.

CO3: Learn and understand about the basic concepts of fluid and magneto fluid dynamics and apply this fundamental knowledge for understanding electric arc in welding.

CO4: Understand and interpret about metal transfer and mass flow in the weld pool and apply this knowledge for understanding its implications on the weld strength.

CO5: Learn and understand the concept of high power density welding.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S								S			S
CO2	S		S						S			S
CO3	S		S						S			S
CO4	S	S		S					S		S	S
CO5	S		S									

Theory:

SECTION I

PHYSICAL PROPERTIES OF FLUIDS AT ELEVATED TEMPERATURES

Introduction, gases, dissociation and ionization, the equation of state of a gas at elevated temperature, the equilibrium constant, evaluating the degree of dissociation and ionization, specific heat, transport phenomena, particle encounters in a slightly ionized gas, particle encounters in an highly ionized plasma, electrical conductivity, thermal conductivity, viscosity, calculating the transport coefficients, liquid metals, vapour pressure, surface tension, viscosity

6

ELECTRICITY AND MAGNETISM

Fundamentals like Electrons and ions, electrostatics, Gauss's law, the magnetic force, the law of Biot and Savart, electromagnetic induction, the Maxwell stress and the force on a conducting body, the force acting on a liquid drop carrying an electric current, the current density and ohms law, the pinch instability: an approximate solution, the dynamics of instability in fluid cylinder, predicted behaviour of perturbed cylinder: radial pinch, higher unstable modes, the effect of an externally applied magnetic field, the growth rate constant, the effect of viscosity on the instability of a fluid cylinder.

6

FLUID AND MAGNETO FLUID DYNAMICS

Introduction, the continuity equation, the momentum equation, momentum, pressure, viscosity, Lorentz force, other forces, and the equilibrium condition, the stream function, the components of stress, the Bernoulli equation, solutions of the momentum equation, laminar flow from a point source of momentum with no electric current: the steady jet, the fluid pressure in the jet, the steady jet with a heat source, laminar flow from a point source in a semi-infinite fluid (no electric current), laminar flow in a semi-infinite fluid having a point source of current in the plane ($\theta=\pi/2$), laminar flow in a semi-infinite fluid: the linear solution, the time-dependent development of flow due to a point source of current in a semi-infinite region, breakdown of the solution to the non-linear problem, other limitations to analytical solutions of the momentum equation, laminar flow in a liquid drop immersed in a conducting fluid carrying an electric current, distortion of the liquid drop, an ellipsoid of revolution in a conducting fluid: the drag coefficient, laminar flow in a hemisphere having a point source of current at the origin, flow in a container induced by a distributed current source.

6

THE ELECTRIC ARC

Introduction, general description of glow and arc discharges, principal characteristics of the electrode regions of arcs, high electric and thermal fields, contraction, classification based on degree of contraction: range of observed current density, glow and arc cathode; glow and arc plasma; glow and arc cathode and abode falls, distinction between thermionic and non-thermionic cathodes, the lo voltage non-thermionic cathode, surface clean up and movement in magnetic field including retrograde motion, vapour and plasma jets; force on cathode, electrode material and surface state, mature of gas or vapour, value of current, gas pressure; vacuum arcs, theories of the cathode mechanism, the glow cathode: the thermionic cathode, theories of the non-thermionic cathode, the arc column, the anode, theory of glow anode, anode fall voltage and current density, energy balance at the anode, plasma and vapour jets.

6

SECTION-II

THE ELECTRIC ARC IN WELDING

Introduction, structural features, overall electrical characteristics, the total arc characteristics at various pressures, relationship between power source and arc characteristics, arc efficiency, cathode phenomena, cathode phenomena, cathode phenomena and characteristics: thermionic cathodes, the potential drop adjacent to a thermionic cathode, cathode phenomena and characteristics: non-thermionic cathodes, anode phenomena, anode characteristics, the anode at the tip of the rod, the heat balance at the anode, the depth of the anode drop zone, the arc column, the energy flux in the arc column, the ac column temperature, mass flow in the arc column, the effect of pressure variation on the arc column, calculating mass and heat flow in the arc column, arc stiffness and arc blow, controlling arc stiffness and arc force.

8

METAL TRANSFER AND MASS FLOW IN THE WELD POOL

Metal transfer, introduction, the effect of static forces in drop detachment, the pinch instability in GMA welding, other unstable modes, the burn off rate, the drop temperature, the drop transfer rate, the pinch model applied to the droplet transfer rate, transfer of drops across the arc, the arc force, the weld pool, flow in the weld pool, the weld pool temperature, the shape of the weld pool and the reinforcement bead, the effect of composition and surface condition on the shape of the weld pool.

8

HIGH POWER DENSITY WELDING

Introduction, keyholing, range of power densities in welding processes (a) high power densities, (b) intermediate power densities, (c) & (d) low power densities, threshold power density for vaporization, size of the keyhole, discussion on forces acting within the keyhole, forces tending to form and maintain the keyhole like beam pressure, vapour pressure, recoil pressure, ; forces tending to close the keyhole like Gravitational pressure, Surface tension pressure, pressure balances for a generalised keyhole a) bottom of the keyhole (closed), b) sides of the keyhole, moving weld pool.

8

Reference books:

1. The Physics of Welding by J. F. Lancaster, Publisher: Pergamon Press.
2. Advanced joining technologies by T. W. Eager, Publisher: Chapman & Hall

Subject Code : MET 815F

Title of the course : SAFETY IN WELDING

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Identify the need of safety and various factors affecting it during welding.

CO2: Understand the various Safety rules & regulations as applicable to welding operations.

CO3: Apply various safety management techniques in welding operations.

CO4: Gain an understanding about various safety equipments used in welding.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S											
CO2	S											
CO3		S	S			S		S	S	S		S
CO4	S								S			

Theory:

Section I

Concept of safety 8

Introductions, definitions, need of safety, factors affecting safety, safety and productivity

Safety rules and regulations 8

The factories act 1948, factories act amendments in 1987 and their implications, salient features of the amendments 1987, implications of the 1987 amendments.

Safety precautions against fire 8

Causes of industrial fire, preventive measure to be taken against fire, handling of the fire accidents

Safety in welding 8

Causes of Hazards associated with gas and arc welding processes, protection against electric shock, arc radiations, fumes and dust, compressed gases and fire explosions.

Section II

Safety management techniques 8

Safety inspections; procedures, periodicity, checklist, report form, planning for safety, safety sampling, safety audit, safety survey, incident recall technique, Job safety analysis, damage control, disaster control

Safety equipment 8

Various safety equipment, constructional features, handling, maintenance and repair of safety equipment

Recommended Books:

1. Moore, *"Manufacturing Management*", MGH Pub.
2. Khanna O.P, "*Industrial Engineering*, Dhanpat Rai Pub.
3. Maymard,"Handbook of Industrial Engineering", MGH Pub.
4. Parmar R.S,*"Welding Process Technology",* Khanna Pub.

Subject Code : MET-815G (Elective-I)
Title of the course : Computer Aided Engineering

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: To learn & understand fundamentals related to CAD and use the same in the relevant areas.

CO2: To learn & acquire knowledge about finite element methods & its utilization of different research problems.

CO3: To learn, understand, plan, execute and analysis different programming related to computer aided manufacturing systems.

CO4: To learn & acquire knowledge about utilization of computers in manufacturing systems.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S		S									S
CO2	S	S	S	S								S
CO3	S	S	S	S								S
CO4					S							S

Theory:

SECTION I

Computer Aided Design (CAD) **12**

Interaction devices and techniques, geometrical transformations, viewing in three dimensions, modeling and object hierarchy, raster algorithms, display, representation of 3D shapes, introduction to cading & rendering of surfaces and solids, hidden lines, edge and surface removal.

Finite Element Method **12**

Modeling, shape functions, finite element equations, boundary conditions, quadratic shape functions, linear, triangular and four elements, numerical integration, software.

SECTION II

Computer Aided Manufacturing **24**

Review of NC part programming, APT programming, computerized numerical control, adaptive control system. Industrial robots, Computer integrated Manufacturing Systems, DNC System, the manufacturing cell, flexible manufacturing systems, computer managing system, Enterprises Resource Planning (ERP), factory of the future.

Material handling and storage systems, group technology, quality control and automated inspection.

Computer networks for manufacturing, hierarchy, local area network, manufacturing automation protocol.

Books Recommended

1. Chandrupatla & Belegandu, Introduction to Finite Elements in Engineering, PHI.
2. Yoram Koren, Computer Control of Manufacturing System, Mcgraw Hill.
3. Mikell P. Grover, Automation, Production systems and Computer Integrated Manufacturing, PHI.
4. Ramamurthi, Computer Aided Mechanical Design & Analysis, TMH.

Subject Code : MET 827

Title of the course : REPAIR RECLAMATION AND SURFACING

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Understanding the need and requirement of repair welding.

CO2: Classification of repair welding procedures.

CO3: To understand various surfacing and reclamation techniques.

CO4: To gain knowledge about various surfacing materials and their applications.

CO5: To know about recent developments in surfacing technology.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S											S
CO2												
CO3	S											
CO4		S	S									
CO5				S					S		S	

Theory:

SECTION I

Repair Welding **8**

Need and requirement, Engineering aspects of repair welding - techno-economics aspects, repair welding procedures for components made of steel casting and cast iron, cast iron repair, classification of repair welding procedures according to the size. Some general examples of repair welding viz. Connecting rod, iron pulley, iron plate, shafts or carriage wheels etc.

Temper bead welding **8**

Special procedures to avoid post-repair stress relief heat treatments; half bead, temper bead techniques, usage of different alloys filler metals.

Repair Welding for specific applications **8**

Damaged bends in gas transmission pipeline, heat exchanger repair techniques-explosive expansion, plugging, etc., creep damaged high temperature components, repair of cracked petroleum pressure vessel/reactor.

SECTION II

Surfacing and Reclamation **8**

Surfacing- introduction, hardfacing, cladding, buildup and buttering; Some of the common surfacing applications- steel plants, power plants, earth moving equipments, agricultural implements, chemical & petrochemical industries, etc,

Surfacing Materials **8**

Types of surfacing alloys- Iron based alloys, nickel based alloys, chromium based alloys, cobalt based alloys and copper based alloys; their characteristics; factors to be considered in selection of surfacing alloys.

Welding Processes/Techniques for surfacing **8**

Capabilities of various processes with respect to surfacing and recent developments in these; concept of weld cladding, various techniques used for cladding, cladding materials, areas of applications; various thermal spraying techniques, spraying materials along with applications; use of different surface coatings along with areas of applications.

Books Recommended

1. Dobly R.E., Kent K.S., „Repair and Reclamation", The Welding Institute, 1986
2. „Maintenance Welding in Nuclear Power Plants", American Welding Society, 1988.
3. „Recommended Practice for Repair welding and Fabrication Welding of Steel Casting", Steel Foundry Research Foundation , 1981.
4. Lim Cottrel C., The Welding Institute, „Welding Cast Irons", 1991.
5. „Weld Surfacing and Hardfacing". The Welding Institute, 1987.
6. Nagendra Reddy A., „Maintenance Welding Made Easy", Jaico Publishing House, 1997

Subject Code : MET 828

Title of the course : WELDING METALLURGY

L	T	P	Credits	Weekly Load
3	1	2	5	6

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Learn and understand the concept of heat flow in welding besides making calculations regarding heat flow in welding.

CO2: Understand about different Gas-metal and Slag-metal reactions in welding.

CO3: Understand about various solidification concepts related to welding and apply this knowledge for interpretation of weld microstructures.

CO4: Learn and understand various weldability tests and weldability of various ferrous and non-ferrous alloys

CO5: Understand the concept of residual stresses and distortion in welding and apply this knowledge for actually measurement of distortion on experimental welds.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1		S	S	S								
CO2	S	S	S									
CO3	S	S	S	S	S							
CO4	S	S	S									
CO5		S	S		S							S

Theory:

SECTION I

Heat flow in welding: Different zones of a weldment, heat flow - temperature distribution and weld thermal cycles, cooling rate - influence of heat input, joint geometry, plate thickness and preheat, Heat source, analysis of heat flow in welding, effects of welding parameters

Chemical reactions in welding: Gas-metal and Slag-metal reactions in welding

Fluid flow and metal evaporation in welding: Fluid flow in arcs and weld pools, metal evaporation

Weld Metal Solidification
(i) Epitaxial and non-epitaxial growth at fusion boundary, competitive growth in fusion zone, grain structure control, role of welding parameters on grain structure, nucleation mechanisms in weld metal
(ii) Solidification modes, dendrite and cell spacing, grain structure refinement

Weldability & weldability tests
Weldability: definition, factors affecting weldability
Fabrication weldability tests: Hot cracking and cold cracking tests **24**

SECTION II

Residual Stresses and Distortion
Residual stresses: Introduction, causes, methods of reducing residual stresses in welds
Distortion: Introduction, causes, methods of controlling distortion in welds **12**

Weldability of specific materials
Weldability of carbon steels, stainless steels, high alloy steels, cast irons, nickel alloys, copper alloys, aluminium alloys, magnesium alloys, titanium alloys **12**

Books recommended:
1. Linnert G. E.,*Welding Metallurgy* Volume I and II, 4th Edition, AWS.
2. Granjon H., „*Fundamentals of Welding Metallurgy*, Jaico Publishing House.
3. Kenneth Easterling, „*Introduction to Physical Metallurgy of Welding*, 2nd Edition, Butterworth Heinmann.
4. Saferian D., *The Metallurgy of Welding*, Chapman and Hall.
5. Metals Hand book , Volume VI, American Society of Metals.
6. J.F.Lancaster, *Metallurgy of Welding*, Wood head.
7. Kou S., *Welding Metallurgy*, John Wiley.
8. R. S. Parmar, *Welding Engineering & Technology*, Khanna Publishers.

Subject Code : MET 829

Title of the course : ADVANCED WELDING PROCESSES

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to:

CO1: Understand need & applications of advanced welding processes.

CO2: Selection of particular welding process based on criticality & job requirement.

CO3: Application of various welding techniques for metal cutting applications.

CO4: Application of welding technique in Space and in underwater conditions.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S											S
CO2			S									
CO3		S	S						S			
CO4		S		S					S			

Theory:

SECTION I

Solid State Welding Processes **6**

Friction, inertia and friction stir welding, ultrasonic welding, adhesive bonding, diffusion bonding, explosion welding- basic principle, process variables, weld characteristics advantages, limitations and applications.

High Energy Beam Welding Processes **8**

Electron Beam Welding (EBW) - basic principle, equipment details, process characteristics, process variables, advantages, limitations and applications.

Laser Beam Welding (LBW) – principle of operation, different laser mediums, advantages, limitations and applications.

Electro Slag and Electro Gas Welding **6**

Principle of operation, equipment details, process variations, advantages, limitations and applications.

Thermit Welding **4**

Basic principle, thermit mixtures, pressure thermit welding, applications.

SECTION II

Thermal Cutting **6**

Oxy-Acetylene cutting-basic principle, metal powder cutting, chemical flux cutting, oxygen lancing; Arc cutting- brief introduction to oxygen arc cutting, air arc cutting, plasma arc cutting, metal arc cutting and gouging; advantages, limitations and applications of various techniques.

Brazing and Soldering **6**

Introduction, brazing vs. soldering, various techniques, their advantages, limitations and applications; brazing & soldering consumables.

Underwater Welding **6**

Introduction, problems encountered in under water welding, types of under water welding, Processes that can be applied for under water welding, applications of under water welding, introduction to under water cutting process.

Welding in space **6**

Introduction, problems encountered in space welding, zero gravity, processes that can be applied for space welding.

Books recommended

1. S.V.Nadkarni, “Modern Arc Welding Technology”, Oxford & IBH.
2. H.B.Cary, “Modern Arc Welding Technology”, Englewood Cliffs, Prentice Hall.
3. Leonard P Connor, Welding Hand book, Volume I-III, AWS.
4. Metals Hand book , Volume 6, American Society of Metals.
5. Dave Smith, “Welding skills and technology”, McGraw Hill.

Subject Code : MET 830

Title of the course : WELDING CODES AND STANDARDS

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to:

CO1: Understand various welding codes & standards.

CO2: Gain knowledge about industrial materials, welding consumables and their applications.

CO3: Prepare WPS and PQR for various industrial welding applications.

CO4: Understand basic testing methods for weld qualification.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S											
CO2	S								S			
CO3	S	S				S		S				S
CO4	S											

Theory:

SECTION I

Welding Symbols **8**

Primary and secondary weld symbols, various information and location of this information on welding symbol.

Structural Welding Codes **8**

Introduction to structural welding code AWS D1.1, design requirements, allowable stress values, workmanship and inspection.

Pressure Vessel Fabrication **8**

Introduction to ASME section VIII- division I, design requirements, fabrication methods, joint categories, welding and inspection requirements, post weld heat treatment and hydro-testing.

SECTION II

Welding Procedure and Welder Qualification **8**

Introduction to ASME section IX; introduction to Welding Procedure Specification (WPS)- essential, non-essential and supplementary essential variables, procedure qualification, Procedure Qualification Records (PQR); welders performance qualification, essential and non-essential variables, retest and re-qualification of welders. F Number, P Number and A numbers, Introduction to European standards.

Materials and Consumables **8**

Introduction to ASME section II part A and C; introduction to materials standards and testing of materials, consumables testing and qualification as per ASME/AWS requirements, Storage and handling of welding consumables.

Petroleum Piping and Cross Country Pipeline Welding **8**

Introduction to API 5L code; Process and product standards for manufacturing of pipes - welding procedure and welder qualification, field welding and inspection requirements.

Books Recommended:

1. AWS D1.1 Structural Welding Code
2. ASME Section VIII - Division 1
3. ASME Section IX
4. ASME Section II Part A and Part C

Subject Code : MET-825A (Elective-II)

Title of the course : Fabrication & Processing of Composites & Ceramics

L	T	P	Credits	Weekly Load
3	1	0	4	4

COURSE OUTCOMES:

After successful completion of course, the students should be able to

CO1: Comprehend with the application of manufacturing process of composite materials.

CO2: Differentiate the mechanical behaviour of layered composites compared to isotropic materials

CO3: Describe fundamental fabrication processes for polymer matrix, metal matrix, and ceramic matrix composites.

CO4: Select a suitable composite material for specific application.

CO5: Analyze and extend a given course subject, compose a report paper and effectively communicate the essentials through an oral presentation.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	S	S	M	M			M		M	M
CO2	S	S	S	S		M					M	M
CO3	S	S	S	S	M	M		M				M
CO4	S	S	S	S		M			M		M	M
CO5	S	S	S	S		M		S				S

Theory:

SECTION I

Introduction **12**

General introduction to composites; historical background; concept of matrix and reinforcement and particulates.

Matrix and reinforcement

Types of matrix and reinforcement; Whiskers; volume fraction and weight fraction; Fiber architecture; fiber packing arrangements,

Fabrication methods of polymer composites **12**

liquid resin impregnation routes, pressurized consolidation of resin prepegs, consolidation of resin molding compounds, injection molding of thermoplastics, hot press molding of thermoplastics.

Fabrication of ceramic composites

powder based routes, layered ceramic composites, carbon/carbon composites and applications

SECTION II

Fabrication routes of metal matrix composites **12**

Squeeze infiltration, stir casting, spray deposition, powder blending and consolidation, diffusion bonding of foils, PVD; CVD

Testing and characterization

Different tests like internal stress measurement by diffraction, metallographic preparation with special emphasis to metal matrix composites

Secondary processing and application of composites **12**

Secondary processing like machining, joining, extrusion of composites; Application and case studies.

Recommended Books:

Title	Author(s)	Publisher
An Introduction to Composite Materials	Hull D and Clyne TW	Cambridge University Press
Metal matrix composite	R.K.Everret & R.J. Arsenault	Academic Press

Introduction to metal Matrix Composite	T. W. Clyne & P. J. Withers	Cambridge Press
Composite Materials Science and Engineering	Chawla, Krishan K	Springer
Composite Materials and Processing	M. Balasubramanian	CRC Press
Mechanics of Composite Materials	Jones, R.M	Taylor and Francis
Fiber-Reinforced Composites Materials, Manufacturing and Design	P. K. Mallick	CRC Press

Subject Code : MET 825 F

Title of the course : WELDING COST AND ECONOMICS

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to:

CO1: Gain knowledge about cost associated with various welding processes & selection criteria.

CO2: Understand about various welding consumables and their cost impact.

CO3 Understand various tooling and accessories essential for welding and their influence on welding costs.

CO4: Understand terminology associated with welding costs and apply this knowledge for calculating welding cost.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S						S					
CO2									S			
CO3	S											S
CO4		S	S	S			S					

Theory

Section I

Factors influencing welding cost

Welding process, joint design, consumables, welding procedures-brief introductions. 4

Selections of welding process

Factors to be considered in selecting the welding process, their effect on total welding cost, cost curves for different processes. 6

Selection of joint design

Types of weld joints, cost involved in joint preparations, comparison of amount filler metal requirement for different joint design. 6

Welding consumables

Consumables for varies processes- their characteristics, (metal recovery, electrode efficiency, stub down away etc,) advantages and limitations of various types/ forms of consumables and their effect on over all welding cost. 6

Section II

Welding procedures

Various components of a welding procedure and their contribution toward welding cost, welding position- operator efficiency , operation factors, use of jigs, fixtures, petitioners and other mechanized welding system- their effect on welding cost. 12

Costing for welding

Definition for terms, composition of welding cost- equipment cost, cost of consumables, labor cost, over head cost, total cost- method of calculating these cost, standard time and method of calculating standard time. 12

Books Recommended

1. S.V. Nadkarni, Modern arc welding technology, Oxford & IBH
2. T.H. North, Advanced welding technology, chapman and Hall.
3. Leonard P Conner, Welding hand book, Volume III, AWS.
4. H.B. Caary, Modern arc welding technology.
5. R.S. Parmar, Welding processes and technology, Khanna publishers.

Subject Code : MET 825G (Elective-II)

Title of the course : WELDING APPLICATION TECHNOLOGY

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Apply different welding techniques used in power generation equipment.
CO2: Understand the welding requirements in petroleum and refinery industry.
CO3: Apply knowledge of welding in Structural, ship building and automobiles applications.
CO4: To gain knowledge about materials, processes, fabrication procedures in aerospace, nuclear and pressure vessels industries.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1									S			
CO2	S											S
CO3		S				S						
CO4	S			S							S	

Theory:

SECTION I

Boilers and pressure vessels 9

Materials, processes, fabrications, inspection and testing.

Power generation equipment 10

Heat exchangers, power cycle piping, supper heaters, reheaters, economizer, auxiliary pipe materials, welding and testing/ inspections.

Structural, ship building and automobiles 10

Materials, processes, fabrications and constructions, use of automatic welding and system in automobiles industry, automations, testing and inspection.

SECTION II

Nuclear and aerospace 9

Materials, processes, fabrications, inspections and testing, reasons and stringent quality control measures.

Petroleum and refinery piping 10

Materials, processes, fabrications techniques and filled welding.

Recommended books

1 American Welding Society, "Guide for Steel Hull Welding".
Gooch T. S., "Review of Overlay Welding Procedure for Light Water Nuclear Pressure Vessels, American Welding Society.

2. Winter Mark H., Materials and Welding In Off- Shore Constructions, Elsevier.
3. Welding Institute in Canada. „Welding for challenging environment" Pergamon Press.
4. Lincoln Arc Welding Foundations, „Modern Welding Structures" Volume I- IV.
5. Lincoln Arc Welding Foundations, „ Arc Welding Projects", Volume I and II.
6. Lincoln Arc Welding Foundations, „Arc welding in manufacturing and Constructions", Volume I and II

7. Adams C.M. and Corrigan, „Mechanical and Metallurgical behavior of Restrained welds in Submarine steels", American Welding Society.

Subject Code : MET 913

Title of the course : DESIGN OF WELDED STRUCTURES

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Understand the importance of material properties and learn about weld joints, weld symbols and principles of joint design used in welding.

CO2: Analyze the welded joints subjected to different types of loading conditions (static as well as dynamic like fatigue) and make calculations regarding weld size accordingly.

CO3: Learn, understand, identify and predict about different types of fracture in welds.

CO4: Understand the concept of fracture toughness in welding.

CO5: Learn, calculate and gain knowledge about estimation and costing involved in welded fabrications.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S											
CO2		S	S	S	S				S			
CO3	S			S				S			S	
CO4				S							S	
CO5	S			S								S

Theory:

SECTION I

PROPERTIES OF MATERIALS **6**

Importance of properties, tensile, compressive, shear, fatigue, impact

WELD JOINTS, WELD SYMBOLS AND PRINCIPLES OF JOINT DESIGN **6**

Welded joints and their types, types of welds, weld symbols, general and specific joint design principles

FUNDAMENTALS OF DESIGN AND WELD DESIGN FOR STATIC LOADING **6**

Introduction to analysis by bending, shear deflection in beams, deflection of curved beams, designing for torsional loading, calculations for weld size

Cases of different types of welded joints: Parallel fillet, transverse fillet, circular fillet weld subjected to torsion and bending moment, Butt joints

WELD DESIGN FOR DYNAMIC LOADING **6**

Fatigue loading of welds: Characteristics of fatigue failure, fracture mechanism, types of fatigue failure, factors affecting fatigue life, techniques/methods for improving fatigue life of welded structures

.

SECTION II

FRACTURE TOUGHNESS IN WELDING **12**

Introduction to fracture toughness, Types of fracture: ductile and brittle, factors affecting types of fracture, Plane stress and plane strain conditions in welds, Modes of crack extension in materials.

Classification of engineering materials on the basis of fracture toughness

Methods for determining fracture toughness of welds:

(i) Concept of LEFM (Linear elastic fracture mechanics)

(ii) Concept of (EPFM) (Elastic plastic fracture mechanics)

COSTING FOR WELDING **12**

Definition of terms, composition of welding costs- equipment cost, cost of consumables, labour cost, overhead cost, total cost- method of calculating these costs. Standard time and method of calculating standard time.

Books Recommended

1. Omer W. B., „*Design of Weldment*, James.F. Lincoln Arc Welding Foundation, 1991.
2. Gray T. G. E. „*Rational Welding Design*, Butterworths.
3. Hertzberg R.W., „*Deformation and Fracture of Mechanics of Engineering Materials*, John Wiley.
4. Dieter G.,„Mechanical Metallurgy, Tata McGraw Hill.
5. Guerey T.R., „Fatigue of Welded Structure, Cambridge University Press.
6. Broek, Elementary Engineering Fracture Mechanics, Kluwer Academic Publishers.
7. R. S. Parmar, *Welding Engineering & Technology*, Khanna Publishers.

Subject Code : MET 912A (Elective-III)

Title of the course : WELDING AUTOMATION

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Learn about the importance of automation in welding.

CO2: Understand the concept of sensors used for welding automation.

CO3: Understand the concept of weld simulation. Make predictions about metallurgical changes in welds and learn means for data acquisition in welding and apply this knowledge for real time monitoring and managing of databases.

CO4: Learn and understand the concept robotics in welding along with developing programming abilities for using robots in welding.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S											
CO2	S		S									
CO3		S	S	S	S			S				S
CO4	S		S	S					S		S	

Theory:

SECTION I

Introduction **12**

Manual, semiautomatic, automatic and mechanized welding; welding processes suitable for automation; basic requirements of a welding power source for automation; recent developments in welding power sources; standard devices used for holding and traversing welding torches and jobs in pipe and plate welding, like welding fixtures, positioners, manipulators, column and boom, turning rolls, side beam carriage, orbital welding systems, etc.

Sensors **12**

Thermal, electromagnetic, optical and sound sensors for sensing current, voltage, welding speed, temperature, no.of drops, etc., contact and non-contact sensors; seam tracking and adaptive control.

SECTION II

Computers in Welding **12**

Off line planning like weld simulation, design, prediction of metallurgical changes and properties; computerized weld testing and inspection; computerized data acquisition and sensing systems; modeling of welds and welding processes; with soft computing techniques using evolutionary algorithms, real time welding information and control systems; welding documentation (WPS, PQR, etc.); databases and knowledge base systems.

Robotics in Welding **12**

Introduction to robots, robot selection and its applications for welding; programming of welding robots; tolerances of assemblies for robot welding; sensors and auxiliary devices for robot welding; new generation robots, adaptive control in welding.

Books recommended

1. Welding robots, British welding Institute.
2. Proceedings of international conference on computer tech. in welding, IIW.
3. S.V.Nadkarni, “Modern Arc Welding Technology”, Oxford & IBH.
4. T.H. North, Advanced Joining Technology, Chapman and Hall.
5. Leonard P connor, Welding Hand book, Vol. III, AWS.

Subject Code : MET 912B (Elective-III)

Title of the course : PRODUCT DESIGN & DEVELOPMENT

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Understand the prerequisites of the product design & development, concept of product life cycle, including PLM framework, product data management, system integration and quality issues.

CO2: Apply the concept of value engineering and value analysis to product design & development.

CO3: Understand the underlying issues on material and process selection for product design & development.

CO4: Apply the concept of design for manufacture and assembly, and incorporating other life cycle issues at the design stage.

CO5: Understand the principles of engineering ethics and liability issues; and apply the basic tools of design protection,

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	S	M								S
CO2	S	S	S	M								S
CO3	S			M								S
CO4	S	S		M								S
CO5				M		S		S				S

Theory:

SECTION I

Stages in Design process: Introduction to various stages of the design process: Indentify Customer Needs, Establish target specifications, Generate and Test Product concept, Final Specifications, Product architecture, Industrial Design, Case study.

Product life cycle: New product introduction: early introduction, increased product life. Product Lifecycle Management: Product information, PLM framework, Enabling technologies, Product data management (PDM) , Functions of PDM software. System integration, QFD, House of quality, Case studies.

Value engineering: Introduction, nature and measurement of value, Value analysis job plan, Creativity and techniques of creativity, Value analysis test, Case studies

Concurrent/ reverse engineering: Introduction, basic principles, components, benefits of concurrent engineering. Concept of reverse engineering. (24 Hrs)

SECTION II

Material selection: Materials in design, The evolution of engineering materials, Design tools and material data, Function, material, shape and process, Material selection strategy, attribute limits, selection process, COMPOSITECOMPOSITE
material selection, Case studies

Process selection: Introduction, Process classification: shaping, joining and finishing, Systematic process selection, Ranking, process cost, Computer – aided process selection.

Design for manufacture and assembly: Design for Manufacture and Assembly (DFMA), Reasons for non- implementation, Advantages, Design for Manufacture in relation to any two manufacturing processes: machining and injection molding, Need, objectives.

Design for 'X': Introduction, Design for: Safety, quality, reliability, energy conservation, environment, ergonomics, maintenance, recyclability and disposal.

Patents, liability and ethics: Introduction, Protecting your design: patents, copyright, basic tools of design protection. Liability issues in product design. Ethical considerations, Examples/ case studies

(24 Hrs)

Recommended Books: Title	**Author(s)**	**Publisher**
Product Design & Development	Karl T. Ulrich, Steven D. Eppinger	Mc GrawHill
Integrated Product and Process Development	John M. Usher, Utpal Roy and H. R. Parasaei	Tata McGraw Hill
Product Design for Manufacture and Assembly	G. Boothroyd, P. Dewhurst and W. Knight	Marcel Dekker
Product Design and Manufacture	A. K. Chitale and R. C. Gupta	PHI
Selection of Materials and Manufacturing Processes for Engineering Design	Mahmoud M. Farag	Prentice Hall
Material Selection in Mechanical Design	M. F. Ashby	Elsevier
Concurrent Engineering	Biren Prasad	Prentice Hall

Subject Code : MET 912 C (Elective-III)
Title of the course : Manufacturing System Analysis

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

After successful completion of course, the students should be able to

CO1: Understand System Components, system structure; system inputs and outputs and apply the knowledge to problem definition.

CO2: Model formulation, functional and equipment structuring. Linear graph approach. Time models.

CO3: Analyze the dynamic analysis of organization; total flow of man, information and materials; and application to practical organisation

CO4: Formulate and optimise the Optimization of system performance using appropriate techniques.

CO5: Understand the System Design Elements; Game and decision theory and its applications.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO 3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	S	M		S						S
CO2	S	S	S									S
CO3	S	S	S						S			S
CO4	S	S	S	M							S	S
CO5	S	S	S	M							S	S

Theory:

SECTION-I

System Components 12

The environment and the system concept; system structure; system inputs and outputs; system approach to macro problems; problem definition with system concepts and approach.

System Modeling

Model formulation; Representation of dynamics signal and system flow graph; System interactions; System compatibility; Sub-systems and inter-connections; Functional and

equipment structuring. Linear graph approach. Time models.

System Simulation 12

Basic philosophy of simulation; Analog and Digital Computers; System with feedback. Continuous and Discrete system simulation.

SECTION-II

System Dynamics 12

Dynamic analysis of systems; Dynamic behavior of organization; Total flow of man, information and materials; Dynamic analysis of the models for capital equipment and orders; Derivation of the policies for management based on system models.

Optimization 12

Optimization of system performance; Perturbation analysis of system parameters; Criteria for optimization, Gradient method; Dynamic programming method.

System Design

Elements of Decision analysis; Game theory; Application of game and decision theory to system design. Techniques for creative design; Elementary sensitivity analysis.

Recommended Books:

Title	***Author(s)***	***Publisher***
System Engg. Tools	Chestnut,	John Wiley
Design of Engg. Systems	Gosling	John Wiley
System Engg.,	A.D.Hall	Van Nostrand, U.K.
System Engg. Handbook	Machol,	McGraw Hill Inc
Introduction to System Science	G.M.Sandquist	Prentice-Hall
System Modeling and Analysis	Nagrath & Gopal	Tata McGraw Hill
System Simulation	Geoffrey Gordon	Prentice Hall of India
Industrial Dynamics	Forester	MIT Press
Concepts of Engineering System Design	Warren E. Wilson	McGraw Hill,
Realtime System Design and Analysis	P. A. Laplante,	Prentice Hall of India
System Design & Analysis,	Avadh	Galgotia Publishers

Subject Code : MET-912D (Elective-III)
Title of the course : ROBOTICS

L	T	P	Credits	Weekly Load
3	1	0	4	4

Course Outcomes:

CO1: Understand the basic concepts of industrial robotics in terms of classification, kinematics, sensors, and typical applications
CO2: Understand the control techniques used for rehabilitation robots.
CO3: Understand the knowledge on advanced algebraic tools for the description of motion
CO4: Design and implement control applications for autonomous mobile robots.
CO5: Understanding the dynamics of the manipulator.

Pre-requisite knowledge:

CO/PO Mapping : (Strong(S) / Medium(M) / Weak(W) indicates strength of correlation):												
COs	Programme Outcomes (POs)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	S		S							S
CO2	S	S	S									M
CO3	S											S
CO4	S		S		S	S				S		S
CO5	S	S			S	S						S

Theory:

SECTION-I

Introduction 12

Evolution of robot and robotics, laws of robotics, robot anatomy: Links, joints, Degrees of freedom (DOF), Arm configuration, wrist configuration, end-effector

Coordinate Frame, Mapping and Transforms 12

Coordinate frames, description of objects in space, transformation of vectors, inverting a homogeneous transform, fundamental rotation matrices

Kinematics 12

Denavit- Hartenberg Notation, kinematic relationship between adjacent links, Manipulator transformation matrix, Inverse kinematics

Linear and angular velocity of a rigid body, velocity propagation along links, manipulator jacobian

SECTION-II

Dynamics 12

Lagrange-Euler Formulation, Newton-Euler Formulation

Control of manipulators 12

Position control, Force control: Applications of standard control strategies.

Recommended Books:

Title	***Author(s)***	***Publisher***
Robotics and Control	Mittal and Nagrath	TMH
Introduction to Robotics	J.J. Craig	Pearson Education
Vector mechanics	Beer and Johnston	TMH
Control System Engineering	Nise	Wiley
Simulation Modeling & Analysis	David Kelton	Tata McGraw Hill