Curriculum

Ph.D.

Indian Institute of Technology Jodhpur

Ph.D. (Energy) and Ph.D. (Mechanical Engineering)

Cat.	*Course Number: Course Title*	*L-T-P*	*Credits*		*Cat.*	*Course Number: Course Title*	*L-T-P*	*Credits*
I Semester					**II Semester**			
E	*Electives*	3-0-0	3		E	*Electives*	3-0-0	3
		Total					*Total*	
III Semester					**IV Semester**			
TH	**EN799/ME799 Ph.D. Thesis**				TH	**EN799/ME799 Ph.D. Thesis**		
		Total					*Total*	
V Semester					**VI Semester**			
TH	**EN799/ME799 Ph.D. Thesis**				TH	**EN799/ME799 Ph.D. Thesis**		
		Total					*Total*	
VII Semester					**VIII Semester**			
TH	**EN799/ME799 Ph.D. Thesis**				TH	**EN799/ME799 Ph.D. Thesis**		
		Total					*Total*	

Electives

Semester I				Semester II			
ME751	Advanced Fluid Mechanics	3-0-0	3	ME756	Boundary Layer Theory	3-0-0	3
ME752	Theory of Arc Welding Processes	3-0-0	3	ME757	Welding Metallurgy	3-0-0	3
ME753	Vibration in Mechanical Systems	3-0-0	3	ME758	Vibration in Agricultural Implements	3-0-0	3
ME754	Failure Analysis of Welds	3-0-0	3	ME759	Rotor Dynamics	3-0-0	3
ME755	Soil and Water Conservation Engineering	3-0-0	3	ME760	Quality Control of Weldments	3-0-0	3

S.No.	*Category*	*Category Title*	Students with	*Total Courses*	*Total Credits*
1	E	*ELECTIVES*	Master's Degree	4	12
			M. Sc. Degree	10	30
			Bachelor's Degree	10	30
2	H	Thesis	-	-	-

Course Title	***Turbulent Fluid Flow***	Course No.	**ME751**			
Focus Group	Mechanical Engineering	Structure (LTPC)	3	0	0	3
Offered for	PhD	Status			*Elective*	
Pre-requisite	*Consent of Teacher*	To take effect from				

Objectives

1. Provide practical and advanced aspects of fluid flow
2. In real life, most of the encountered flow types in engineering practice are turbulent in nature. Therefore, it is attempted to expose the students to such complex fluid flow phenomena and its applications.

Learning Outcomes

1. Concept on complex/practical fluid flow phenomena
2. Theoretical modelling and analysis methodology of such a flow type
3. Hands-on-experience with widely employed computational tools, like, ANSYS-FLUENT and CFX

Course Content

Basics concept: Fundamental of turbulence, method of analyses, diffusivity, length scales, boundary layers.

Analysis: Characteristic and analysis of turbulent fluid flow: Mixing length models, gradient models, Homogeneity, isotropic turbulence, turbulent heat transfer, energy spectrum, integral scales;

Modelling approaches: Introduction to turbulence modeling- RANS, LES AND DNS; 1-equation, 2-equation Isotropic models and algebraic anisotropic models.

Hands-on-experiences in computational fluid flow: Computational Fluid Mechanics (basic hands on training on computational software e.g. ANSYS-FLUENT;

Application: Solar Thermal system analyses e.g. solar heating, cooling, heat exchange system design

Reference Books

1. Tennekes and Lumley: A First Course in Turbulence, MIT Press
2. Duffie and Beckman: Solar Engineering of Thermal Processes
3. On-line literature and manuals of ANSYS-FLUENT/CFX

Course Title	***Theory of Arc Welding***	Course No.	**ME752**			
Focus Group	Mechanical Engineering	Structure	3	0	0	3
Offered for	Ph.D Students	Status	*Elective*			
Pre-requisite	*Consent of Teacher*	To take effect from	*July 2014*			

Objectives

To impart knowledge and train students in area of arc welding processes

Learning Outcomes

1. Acquire fundamental understanding of the principles of arc welding
2. Develop detailed understanding of Arc welding processes and effect of their process parameters
3. Understand how arc welding processes are selected, controlled, and applied to the various joint design
4. requirements
5. Diagnose faults in arc welding processes and acquire basic understanding of the heat flow and residual stresses in welds

Course Content

Physics of welding arc- Welding arc, voltage distribution along the arc, thermionic and non-thermionic cathodes, arc characteristics and its relationship with power source, arc efficiency, heat generation, effect of shielding gases on arc, isotherms of arcs, Classification, forces acting on the drop, metal transfer mechanisms, transition current, melting rate, effect of polarity, deposition efficiency, current and voltage oscillograms, high speed films. Consumable electrode welding processes. Manual metal arc (MMA) welding: type composition and functions of flux covering, ISI and other international codes for electrodes, concepts of special electrodes, consumables, arc length control in pulsed MIG welding, selection of parameters, self shielded and gas shielded flux cored wire welding.

Submerged Arc and Electrosloag Welding: Specific features, process variables, types and composition of fluxes and their manufacturing, arc length control, significance of flux-metal combination; Electroslag welding-heat generation, principle, wire and consumable guide technique, selection of parameters, nature of fluxes. Non-Consumable Electrode Welding Processes: Gas tungsten arc welding, electrodes, compositions, shielding gases, arc ignition and maintenance, selection of polarity, arc voltage rectification and remedy, cathode spot and normal mode operations. Plasma arc welding: transferred and non-transferred plasma arc welding, selection of gases, welding parameters, keyhole technique.

Arc stud welding, application of external magnetic field during welding, gravity welding, surface tension transfer power source, magnetic arc welding. Heat flow and Residual Stresses in Welds: Heat flow in welding, effect of welding parameters on heat distribution, Calculation of peak temperature, weld thermal cycle, cooling rate and solidification time, residual stress distribution, influence of residual stress in static and dynamic loading.

Reference Books

1. Larry J. and Jeffus L., "Welding Principles and Application", 5th edition, Delmer Publication ,2002
2. Messler R. W., "Principles of Welding (Processes, Physics, Chemistry and Metallurgy)", John Wiley & Sons. 1999
3. "Procedure Handbook of Arc Welding", 14th edition, Lincoln Electric Company,2004
4. "Metals Handbook", Vol. 6, ASM International Publication. 1993
5. "Welding Handbook" Vol. 1, 2 & 3, 9th Edition, American Welding Society. 2001

Course Title	***Failure Analysis of Welds***	Course No.	**ME754**			
Focus Group	Mechanical Engineering	Structure	3	0	0	3
Offered for	Ph.D students	Status			*Elective*	
Pre-requisite	*Consent of Teacher*	To take effect from	*July 2014*			

Objectives

To impart knowledge and train students in area of fracture mechanics and failure analysis

Learning Outcomes

1. Acquire fundamental understanding of the fracture phenomenon of solid materials
2. Develop detailed understanding of fracture mechanics and fatigue
3. Acquire basic understanding of the techniques used to perform failure analysis
4. Learn about large variety of fracture mechanisms and fracture modes associated with failure
5. Become intimately familiar with macrofractographic and microfractographic analysis of failures

Course Content

Revision and clarification of basic concepts: Griffith criterion, ductile and brittle fracture, cyclic fatigue, environmentally assisted crack growth. Linear Elastic Analysis , crack tip stresses, finite size effects, crack opening displacement

Plastic Analysis Hydrostatic stress, deviatoric stress, yield criteria. Elastic-Plastic Analysis, Fracture toughness testing, Crack Growth Resistance - R-curves, General practice in failure analysis, Correlation of weldment failure of different materials using various welding processes including repair welding Mechanical Aspects and Macroscopic Fracture-Surface Orientation

Ductile and brittle failure mechanisms, Cyclic fatigue failure mechanism, Fatigue Crack Propagation, High-Temperature Deformation Response of Crystalline Solid, Stress corrosion cracking and hydrogen assisted failure mechanisms.Application of Safety Concepts to Welded Structures: Material imperfections and stress states in weldments, quality - degradation in welded structures; Case studies as examples of failures; Design and service requirements for engineering structures fabricated by welding

Reference Books

1. R. W. Hertzberg, "Deformation and Fracture Mechanics of Engineering Materials," John Wiley & Sons, 1996 (ISBN: 978-0-471-01214-6).
2. C. R. Brooks and A. Choudhury, "Failure Analysis of Engineering Materials," McGraw-Hill, 2002 (ISBN: 0-07-135758-0).
3. W. D. Callister, "Materials Science and Engineering; An Introduction," 7th Edition, John Wiley & Sons,2007, (ISBN-13: 978-0-471-73696-7).
4. D. Broek, "Elementary Engineering Fracture Mechanics", Springer; 3rd edition, 1986
5. Kathleen Mills, Metals Handbook: Volume 12: Fractography (Asm Handbook) , 1987
6. W. T. Becker, R. J. Shipley ,ASM Handbook: Volume 11: Failure Analysis and Prevention (ASM Handbook) (ASM Handbook), 2002

Course Title	***Soil and Water Conservation Engineering***	Course No.	**ME755**			
Focus Group	Mechanical Engineering	Structure	3	0	0	3
Offered for	PhD	Status	Elective			
Pre-requisite	*Consent of Teacher*	To take effect from	*January 2014*			

Objectives

1. To inculcate the knowledge on basic properties of soil and characterizing them
2. To enable understand various characteristics of extracting, supplying, treating and recycling water

Learning Outcomes

1. To apply water treatment aspects to agricultural and open channel or river supply
2. To manage the fertility and water content in the surface and subsurface in adverse climatic situations

Course Contents

1. Conservation and environment: Classification and Experiments characterizing methods for soils
2. *Existence of water:* Precipitation, Evaporation and Evapotranspiration
3. *Capillary Water :* Infiltration and Runoff/ Seepage Analysis
4. *Open Chanel Flow::* Soil Erosion by Water

Terraces and Vegetated Waterways
Water and Sediment Control Structure
Channel stabilization and Restoration – MIKE 11

5. Water Supply: Domestic Water Supply -EPANET
6. Wetlands – Drainage principles and Surface Drainage: Water table Management
7. Irrigation Principles of Surface Irrigation, Sprinkler Irrigation, Micro irrigation, Pumps and Pumping
8. Soil Erosion by Wind

Reference Books

1. Water in the Energy Industry, Eds: Plappally A K and Lienhard J H, BP Press, 2014.
2. Soil and Water Conservation Engineering , Glenn O Schwab, Delmar D. Fangmeier, and William J. Elliot, 2010
3. Agricultural Water Management, Larry C Brown, 2008, OSU Overholt Drainage Manual

Course Title	***Boundary Layer Theory***	Course No.	**ME756**			
Focus Group	Mechanical Engineering	Structure	3	0	0	3
Offered for	PhD	Status			*Elective*	
Pre-requisite	*Consent of Teacher*	To take effect from				

Objectives

Concept of boundary layer is necessary for understanding and analysis of practical fluid flows. This course aims to provide an insight to the physics of boundary layer theory and its modelling. Furthermore, the effect of boundary layer on the heat transfer phenomena will be discussed.

Learning Outcomes

1. Concept on complex/practical fluid flow phenomena with emphasis on flow and thermal boundary layer theory
2. Theoretical modelling and analysis methodology of such a flow type
3. Hands-on-experience with widely employed computational tools, like, ANSYS-FLUENT and CFX

Course Content

Basics concept: Some features of viscous fluid flow; Fundamentals of laminar and turbulent flow; Laminar and turbulent boundary layer; Fully Developed turbulent flow in a pipe; Boundary Layer on an airfoil; Separation of boundary layer; Field Equations for Newtonian Fluids and Similarity Laws.

Laminar Boundary Layer: Boundary layer equations; Wall Friction and Separation; Dimensional representation; Friction Drag; Plate Boundary Layer; Thermal Boundary Layer; Pradtl Number; Effect of Dissipation;

Turbulent Boundary Layer:

a. Basic Equations of Motion for Turbulent Flows; Closure Problem; Turbulent Fluctuations;
b. Couette Flow: Two-layer structure of velocity field; universal laws of the wall; friction law; turbulence models; heat transfer.
c. Attached and Separated boundary layers
d. Introduction to Thermal Boundary Layers

Hands-on-experiences in computational fluid flow: Computational Fluid Mechanics (basic hands on training on computational software e.g. ANSYS-FLUENT;

Reference Books

1. H. Schlichting and K. Garsten: Boundary Layer Theory
2. Tennekes and Lumley: A First Course in Turbulence, MIT Press
3. On-line literature and manuals of ANSYS-FLUENT/CFXUG201011020 PRIYA DHANDEV

Course Title	***Welding Metallurgy***	Course No.	**ME757**			
Focus Group	Mechanical Engineering	Structure	3	0	0	3
Offered for	Ph.D students	Status			*Elective*	
Pre-requisite	*None*	To take effect from				

Objectives

To provide students understanding of the metallographic examination of ferrous and non-ferrous welded joints and to provide knowledge on the joining of polymeric composites, castings, materials for high temperature application and dissimilar materials.

Learning Outcomes

1. To enable understanding and effective application of physical metallurgy principles to non-equilibrium thermo-mechanical conditions associated with welding
2. Facilitate understanding and familiarity of the joining of dissimilar welds, polymeric composites, and non conventional processes such as Solid state welding processes, Adhesive bonding, Diffusion bonding. Electron beam welding, ultrasonic welding, underwater welding
3. Understand the techniques and processes suitable for welding non-ferrous alloys
4. Evaluate the causes of defects in welds and recommend the procedures and methods necessary to prevent weld defects
5. Understand the principles involved in joining of non-metals

Course Content

Application of physical metallurgy principles to non-equilibrium thermo-mechanical conditions associated with welding.

Weld solidification principles, Chemical Reactions in the welding zone, Welding of castings – cast steel and cast iron, welding of stainless steels, aluminum alloys, copper alloys and Nickel alloys.

Weldability testing, Welding defects and discontinuities, Joining of Dissimilar welds Case studies, welding failures, Welding Consumable development,

Joining of polymeric composites, Joining of materials for low and High temperature application, Solid state welding processes, Adhesive bonding, Joining processes for plastics and ceramics.

Diffusion bonding. Electron beam welding, ultrasonic welding, underwater welding process.

Reference Books

1. Welding Handbook: Welding Processes, Vol. 3 (American Welding Society/Welding Handbook) Eighth Edition,R. L. O'Brien (Editor)
2. Welding Metallurgy, Second Edition, Wiley –interscience Publication, Sindo Kuo,
3. Introduction to the physical metallurgy of welding, K.E. Easterling, Butterworths,1983
4. Welding Metallurgy and Weldability of Stainless steels, Wiley –interscience Publication, John C. Lippold, Damian J. Kotecki,

Course Title	***Vibrations in Agricultural Implements***	Course No.	**ME758**			
Focus Group	Mechanical Engineering	Structure	3	0	0	3
Offered for	PhD	Status	Elective			
Pre-requisite	*Consent of Teacher*	To take effect from				

Objectives

1. To inculcate the knowledge on agricultural implements relating to basic properties of soil and characterizing them
2. To enable understand various processes in agriculture which required design aspects to prevent or minimize vibration

Learning Outcomes

1. To apply knowledge in designing agricultural implements.

Course Contents

Disaggregation : Effect of forced vibration on disaggregation of materials, Electrical pulse discharge for agricultural processes, Transport and separation of soil

Pulses and Excitation: Electro-hydraulic vibration, automatic adjustment, and mechanical vibrations

Soil Processing: Mole plow, Trailed Trencher, Knifing, Deep cultivator, General purpose plow, root and tuber harvesting machines

Sowing and Fertilization: Devices and effect of vibration on placing or sowing seeds, fertilizers and tubers

Harvesting and Post harvesting implement design: Case Details of vibration in threshing, vegetable and tobacco harvesting, transportation and drying operations

Livestock Breeding and application of vibration-removal of silo from trenches, water feed for animals

Reference Books

1. Ajit K Srivastava, Carroll E. Goering, Roger P. Rohrbach; Engineering Principles of Agricultural Machines. American Society of Agricultural Engineers, 1993
2. Christianson, Roger P. Rohrbach; Design in agricultural Engineering. American Society of Agricultural Engineers, 1986
3. Hunt D and W. Lester Farm Machinery Mechanisms. Iowa State University Press 1973
4. Bernacki H, Agricultural Machines Theory and Construction. USDA & National Science Foundation 1972

Course Title	***Rotor Dynamics***	Course No.	**ME759**			
Focus Group	Mechanical Engineering	Structure	3	0	0	3
Offered for	PhD	Status	Elective			
Pre-requisite	*Consent of Teacher*	To take effect from	*July 2014*			

Objectives

1. To impart the concepts, principles and fundamental understanding of the rotor dynamics phenomena
2. To understand the modelling, analysis, identification and condition monitoring of rotor bearing system for analyzing the performance of rotating machinery

Learning Outcomes

The students become familiar with the fundamental aspect of dynamics of rotating machines in helping in the fault detection and diagnostic of rotor bearing system.

Course Contents

Rudiments of Rotor Dynamics; Gyroscopic, Internal damping and fluid film Effects in Rotors; Torsional Vibrations & Transverse Vibrations; Balancing of Rotors; Bearing Dynamic Coefficient Measurement; Instability in Rotors; Sub-Critical Phenomenon in Rotors; Fault Detection Transducers and Monitoring, and Vibration Monitoring; Condition Monitoring and signature analysis of Rotating Machines

Reference Books

1. Vance J.M., Rotordynamics of Turbomachinery, John Wiley & Sons, Inc., NY
2. Lee C.-W., Vibration Analysis of Rotors, Kluwer Academic Publishers, London
3. Goodwin M.J., Dynamics of Rotor-Bearing Systems, Unwin Hyman, Sydney
4. Krämer E., Dynamics of Rotors and Foundations, Springer-Verlag, New York

Course Title	***Quality control of Weld***	Course No.	**ME760**			
Focus Group	Mechanical Engineering	Structure	3	0	0	3
Offered for	Ph.D Students	Status			*Elective*	
Pre-requisite	*Consent of Teacher*	To take effect from	*July 2014*			

Objectives

To provide knowledge of dimensional inspection, destructive testing and NDT methods, Welding Procedure Specification and welder qualification standards, and provide the student with the knowledge to manage health and safety in welding.

Learning Outcomes

1. Acquire fundamental understanding of the weldment testing, the principles of quality management and apply National and International standards to achieve required weld quality.
2. Acquire basic understanding of the destructive and non- destructive testing techniques.
3. Learn about standard procedure for specification and qualification of welding procedure.
4. Become intimately familiar with codes governing welding inspection and Manage workplace practices to ensure adequate health and safety.

Course Content

Types & purposes of weldment testing, important welding terms, symbols for welding and testing. Classification of discontinuities in weldment, occurrence, causes and prevention of discontinuities, location, orientation and extent of discontinuities, method for testing weld and base metal imperfections. Chemical tests, Metallographic tests, Hardness tests, Mechanical test for groove and fillet welds-full section, reduced section and all-weld-metal tensile tests, root, face and side bend tests, fillet weld break tests, fillet weld shear strength test.

Non-Destructive Testing (NDT) of Weldments: Visual inspection, Dye-penetrant inspection, Magnetic particle inspection, Ultrasonic inspection-principle of ultrasonic testing, types of ultrasonic probes, standard blocks for calibration,, Radiographic inspection –principle of radiography, X-ray tubes, gamma-ray sources, interpretation of radiographs, defect discernibility, neutron radiography, Eddy current inspection,: NDT AWS (American Welding Society) standards, Safety in NDT.

Quality control during manufacture: Duties and requirement of an inspector before, during and after welding, codes governing welding inspection, Standard procedure for specification and qualification of welding procedure, operator qualification, standard method of recording of qualification tests, Welding Procedure Specification (WPS), Procedure Qualification Record (PQR) and Welding Performance Qualification.

Reference Books

1. "Welding Inspection", 3rd edition, American Welding Society,2000.
2. "Welding Hand Book", Vol. 5, 7th edition, American Welding Society, 1984.
3. "ASME Code Section IX ", ASME, 1998.
4. "Structural Welding Code – Steel", AWS D1.1:2000 AWS, 2000.
5. "Specifications for Welding Procedure & Performance Qualification",ANSI /AWS B2.1:1998

Course Title	***Quality control of Weld***	Course No.	**ME760**			
Focus Group	Mechanical Engineering	Structure	3	0	0	3
Offered for	Ph.D Students	Status			*Elective*	
Pre-requisite	*Consent of Teacher*	To take effect from	*July 2014*			

Objectives

To provide knowledge of dimensional inspection, destructive testing and NDT methods, Welding Procedure Specification and welder qualification standards, and provide the student with the knowledge to manage health and safety in welding.

Learning Outcomes

1. Acquire fundamental understanding of the weldment testing, the principles of quality management and apply National and International standards to achieve required weld quality.
2. Acquire basic understanding of the destructive and non- destructive testing techniques.
3. Learn about standard procedure for specification and qualification of welding procedure.
4. Become intimately familiar with codes governing welding inspection and Manage workplace practices to ensure adequate health and safety.

Course Content

Types & purposes of weldment testing, important welding terms, symbols for welding and testing. Classification of discontinuities in weldment, occurrence, causes and prevention of discontinuities, location, orientation and extent of discontinuities, method for testing weld and base metal imperfections. Chemical tests, Metallographic tests, Hardness tests, Mechanical test for groove and fillet welds-full section, reduced section and all-weld-metal tensile tests, root, face and side bend tests, fillet weld break tests, fillet weld shear strength test.

Non-Destructive Testing (NDT) of Weldments: Visual inspection, Dye-penetrant inspection, Magnetic particle inspection, Ultrasonic inspection-principle of ultrasonic testing, types of ultrasonic probes, standard blocks for calibration,, Radiographic inspection –principle of radiography, X-ray tubes, gamma-ray sources, interpretation of radiographs, defect discernibility, neutron radiography, Eddy current inspection,: NDT AWS (American Welding Society) standards, Safety in NDT.

Quality control during manufacture: Duties and requirement of an inspector before, during and after welding, codes governing welding inspection, Standard procedure for specification and qualification of welding procedure, operator qualification, standard method of recording of qualification tests, Welding Procedure Specification (WPS), Procedure Qualification Record (PQR) and Welding Performance Qualification.

Reference Books

6. "Welding Inspection", 3rd edition, American Welding Society,2000.
7. "Welding Hand Book", Vol. 5, 7th edition, American Welding Society, 1984.
8. "ASME Code Section IX ", ASME, 1998.
9. "Structural Welding Code – Steel", AWS D1.1:2000 AWS, 2000.
10. "Specifications for Welding Procedure & Performance Qualification",ANSI /AWS B2.1:1998