DEPARTMENT OF MANUFACTURING ENGINEERING

TWO-YEAR M.E. WELDING ENGINEERING (FULL TIME) DEGREE PROGRAMME

CHOICE BASED CREDIT SYSTEM (CBCS) REGULATIONS

R1) CONDITION FOR ADMISSION

Candidates for admission to the first year of the four-semester **M.E. degree programme in Welding Engineering** shall be required to have passed B.E / B.Tech (Mechanical /Production / Manufacturing/Metallurgy /Automobile/Aeronautical/Marine Materials Science Engineering) with at least one elective in Manufacturing Engineering field or graduates of any other authority accepted by the syndicate of this University as equivalent thereto. They shall satisfy the condition regarding qualifying marks and physical fitness as may be prescribed by the syndicate of the Annamalai University from time to time. The candidates who underwent the degree course under a part time scheme should posses two years of professional experience after passing the B.E degree examinations.

R 2) CREDITS

M.E. full-time programme will have duration of four semesters. The number of credits per semester for the full-time programme shall be as follows:

First and Second semesters	:	20 credits per semester
Third Semester	:	12 credits
Fourth Semester	:	13 credits

The total credits for the programme will be 65. For the award of the degree, a student has to earn a minimum of 65 credits.

R 3) DURATION OF THE PROGRAMME

A student of the full-time programme is normally expected to complete in four semesters but in any case not more than four years from the date of admission.

R 4) REGISTRATION FOR COURSES

A newly admitted student will automatically be registered for all the courses prescribed for the first semester, without any option. Every other student shall submit a completed registration form indicating the list of courses intended to be credited during the next semester. This registration will be done a week before the last working day of the current semester. Late registration with the approval of the Dean on the recommendation of the Head of the Department along with a late fee will be done up to the last working day. Registration for the Phase - I and Phase - II shall be done at the appropriate semesters.

R5) ASSESSMENT

The break-up of assessment and examination marks for theory and practical subjects are as follows.

Theory:

First assessment (mid Semester test I)	:	10 marks
Second assessment (mid Semester test II)	:	10 marks
Third assessment (assignments)	:	5 marks
Examination	:	75 marks

Practical:

First assessment (mid Semester test I)	:	15 marks
Second assessment (mid Semester test II)	:	15 marks
Third assessment (maintenance of record)	:	10 marks
Examination	:	60 marks

The thesis Phase I will be assessed for 40 marks by a committee consisting of the Head of the Department, the guide and a minimum of two members nominated by the Head of the Department. The Head of the Department will be the chairman. 60 marks are allotted for the thesis work and viva voce examination at the end of the prefinal semester. The same procedure will be adopted in the final semester also for thesis Phase II.

R6) STUDENT COUNSELLOR

To help the students in planning their course of study and for general advice on the academic programmes the Head of the Department will attach a certain number of students to a member of the faculty who shall function as counselor for those students throughout their period of study. Such counselor shall advise the students, give preliminary approval for the courses to be taken by the students during each semester and obtain the final approval of the Head of the Department.

R7) CLASS COMMITTEE

For each semester, separate class committees will be constituted by the respective Heads of the Departments. The composition of the class committees for each semester except the final semester shall be as follows:

Teachers of the individual courses

A project coordinator (in the prefinal and final semester committee only) who shall be appointed by the Head of the Department from among the project supervisors.

One Professor or Associate Professor, preferably not teaching the concerned class, appointed as Chairman by the Head of the Department.

The Head of the Department may opt to be a member or the chairman.

All counselors of the class and the Head of the Department (if not already a member) or any staff member nominated by the Head of the Department may opt to be special invitees.

The class committee shall meet four times during the each semester.

The first meeting will be held within two weeks from the date of class commencement. In which the types of assessment like test, assignment etc., the first and third assessments and the dates of completion of the assessments will be decided.

The second meeting will be held within a week after the completion of the first assessment to review the performance and for follow-up action.

The second assessment will be the mid-semester test.

The third meeting will be held within a week after the second assessment is completed to review the performance and for follow-up action.

The fourth meeting will be held after all the assessments except the examination are completed for the courses and at least one week before the commencement of the examinations.

During this meeting the assessment on a maximum of 40 marks will be finalized for every student are tabulated and submitted to the Head of the Department for approval and transmission to the Controller of Examinations.

R8) WITHDRAWAL FROM A COURSE

A student can withdraw from a course at any time before a date fixed by the Head of the Department prior to the second assessment, with the approval of the dean of the faculty on the recommendation of the Head of the Department.

R9) TEMPORATY BREAK OF STUDY

A student can take a one-time temporary break of study covering the current semester and / or the next semester with the approval of the Dean on the recommendation of the Head of the Department, not later than seven days after the completion of the mid-semester test. However, the student must complete the entire programme within the maximum period of four years for full-time.

R10) SUBSTITUTE ASSESSMENTS

A student who has missed, for genuine reasons accepted by the Head of the Department, one or more of the assessments of a course other than the end of semester examination may take a substitute assessment for any one of the missed assessments. The substitute assessment must be completed before the date of the fourth meeting of the respective class committees.

A student who wishes to have a substitute assessment for a missed assessment must apply to the Head of the Department within a week from the date of the missed assessment.

R11) ATTENDANCE REQUIREMENTS

To be eligible to appear for the examination in a particular course, a student must put in a minimum of 80% of attendance in that course. However, if the attendance is 75% or above but less than 80% in any course, the authorities can permit the student to appear for the examination in that course on payment of the prescribed condonation fee.

A student who withdraws from or does not meet the minimum attendance requirement in a course must re-register and repeat the course.

R12) PASSING AND DECLARATION OF EXAMINATION RESULTS

All assessments of all the courses on an absolute marks basis will be considered and passed by the respective results passing boards in accordance with the rules of the University. Thereafter, the controller of examinations shall convert the marks for each course to the corresponding letter grade as follows, compute the grade point average and overall grade point average and prepared the grade cards.

		Grade
90 to 100 marks	:	S
80 to 89 marks	:	A
70 to 79 marks	:	B
60 to 69 marks	:	C
55 to 59 marks	:	D
50 to 54 marks	:	E
Less than 50 marks	:	RA
Withdrawn from the Examination	:	W

A student who obtains less than 30 marks out of 75 in the examination or is absent for the examination will be awarded grade 'RA'.

A student who earns a grade of S, A, B, C, D or E for a course is declared to have successfully completed that course and earned the credits for that course. Such a course cannot be repeated by the student.

The following grade points are associated with each letter grade for calculating the grade point average and overall grade point average.

S – 10; A – 9 ; B – 8; C – 7; D – 6 ; E – 5 ; RA – 0

Courses with grade W are not considered for calculation of grade point average (GPA) or Cumulative grade point average (CGPA), 'RA' grade will be considered for computing GPA and CGPA.

A student can apply for re-totalling of one or more of his / her examination answer papers within a week from the date of issue of grade sheet to the student on payment of the prescribed fee per paper. The application must be made to the controller of examinations with the recommendation of the Head of the Department.

After results are declared, grade cards will be issued to the students. The grade card will contain the list of courses registered during semester, the grades scored and the grade point average for the semester.

GPA is the sum of the products of the number of credits of a course with the grade point scored in that course, taken over all the courses for the semester, divided by the sum of the number of credits for all courses taken in that semester. CGPA is similarly calculated considering all the courses taken from the time of admission.

The results of the final semester will be withheld until the student obtains passing grades in all the subjects of all the earlier semesters.

R13)AWARDING DEGREE :

After successful completion of the programme, the degree will be awarded with the following classifications based on CGPA.

For First Class with Distinction the student must earn a minimum of 65 credits within four semesters for full-time from the time of admission, pass all the courses in the first attempt and obtain a CGPA of 8.25 or above.

For First Class, the student must earn a minimum of 65 credits within two years and six months for full-time from the time of admission and obtain a CGPA of 6.75 or above.

For Second class, the student must earn a minimum of 65 credits within four years for full-time from the time of admission.

R14) RANKING OF CANDIDATES

The candidates who are eligible to get the M.E degree in First Class with Distinction will be ranked on the basis of CGPA for all the courses of study from I to IV semester for M.E full-time.

The candidates passing with First Class and without failing in any subject from the time of admission will be ranked next to those with distinction on the basis of CGPA for all the courses of study from I to IV semester.

R15) ELECTIVES

The student has to select two electives in first semester and another two electives in the second semester from the list of Professional Electives. The student has to select two electives in third semester from the list of Open Electives. The student is also allowed to complete these two open electives in the first and second semester itself as an additional paper, if he/she is willing to go to the Industry for doing Thesis Phase I & II. For such candidates no classes will be handled but a Teacher will be allotted for evaluation of Internal Assessment.

R16) TRANSITORY REGULATIONS

If a candidate studying under the old regulations M.E. could not attend any of the courses in his/her courses, shall be permitted to attend equal number of courses, under the new regulation and will be examined on those subjects. The choice of courses will be decided by the concerned Head of the department. However he/she will be permitted to submit the thesis as per the old regulations. The results of such candidates will be passed as per old regulations.

The University shall have powers to revise or change or amend the regulations, the scheme of examinations, the courses of study and the syllabi from time to time.

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SUBJECTS OF STUDY AND SCHEME OF EXAMINATIONS

FIRST SEMESTER

Code	Subject	Ins. Hours per week		Exam Duration in hours	Internal Assessment marks	End Exam marks	Total marks	Credit Points
		Lec	Lab					
WE101	Welding Power Sources	3	- -	3	25	75	100	3
WE102	Welding Processes-I	3	- -	3	25	75	100	3
WE103	Welding Metallurgy-I	3	- -	3	25	75	100	3
WE104	Resistance and Solid State Welding Processes	3	- -	3	25	75	100	3
WE105	Professional Elective I	3	- -	3	25	75	100	3
WE106	Professional Elective II	3	--	3	25	75	100	3
WE107	Metal Joining Lab	- -	6	3	40	60	100	2
	Total	**18**	**6**		**190**	**510**	**700**	**20**
	Cumulative Total							**/20**

SECOND SEMESTER

Code	Subject	Ins. Hours per week		Exam Duration in hours	Internal Assessment marks	End Exam marks	Total marks	Credit Points
		Lec	Lab					
WE201	Welding Processes-II	3	- -	3	25	75	100	3
WE202	Welding Metallurgy-II	3	- -	3	25	75	100	3
WE203	Design of Weldments	3	- -	3	25	75	100	3
WE204	Non Destructive Testing	3	--	3	25	75	100	3
WE205	Professional Elective III	3	- -	3	25	75	100	3
WE206	Professional Elective IV	3	- -	3	25	75	100	3
WE207	Weldability Testing & Evaluation Lab	- -	6	3	40	60	100	2
	Total	**18**	**6**		**190**	**510**	**700**	**20**
	Cumulative Total							**/40**

THIRD SEMESTER

Code	Subject	Ins. Hours per week		Exam Duration in hours	Internal Assessment marks	End Exam marks	Total marks	Credit Points
		Lec	Lab					
WE301	Open Elective I	**3**		3	25	75	100	3
WE302	Open Elective II	**3**		3	25	75	100	3
	Thesis Phase I and Viva Voce	- -	--	- -	40	60	100	6
	Total	**6**	**--**		**90**	**210**	**300**	**12**
	Cumulative Total							**/52**

FOURTH SEMESTER

Code	Subject	Ins. Hours per week	Exam Duration in hours	Internal Assessment marks	End Exam marks	Total marks	Credit Points
	Thesis Phase II and Viva Voce	- - - -	- - -	40	60	100	13
	Total			**40**	**60**	**100**	**13**
	Cumulative Total						**/65**

WE 101: WELDING POWER SOURCES

OBJECTIVES:

To understand the features of arc welding power sources.

To get the knowledge on selecting the power sources for different arc welding processes.

Classification of power sources – basic features of the arc welding power sources – volt- ampere characteristics of a welding power source – External static volt ampere characteristics – constant current characteristics – constant voltage characteristics – Selection of a static volt ampere characteristics for a welding process – Duty cycle

Basic principles - different methods of control of volt-ampere characteristics, Operation - volt control, slope control, dual control use of chokes and saturable Reactors, Resistance welding transformers. Welding rectifiers, choice of diode material, various types of control of output characteristics, Use of thyristors.

Alternators and D.C. generators for welding three-brush generator, setting of power source characteristic. DC motors, synchronous motors. Choice of power sources for different welding processes.

General theory of rectifier design – solid state welding rectifiers – SCR welding power source – Pulsed arc welding power sources – Transistor welding power sources – Inverter based multi process power source units. Power sources for GTAW & plasma arc welding – Power sources for GMAW/CO_2 welding

Measurement of welding current, voltage temperature, load and displacement, X-Y and strip chart recorders, CRO, LVDT, arc welding analyser, resistance-welding monitor.

REFERENCE BOOKS:

1. Welding Handbook (Welding Processes), Volume II, 9th Edition, American Welding Society (AWS), 2003.
2. Richardson V. D., 'Rotating Electric Machinery and Transformer Technology', 4th Edition, Prentice Hall of India, 1996
3. Parmer R. S., 'Welding Processes and Technology', Khanna Publishers, 2011
4. Say M. G. Ed., Electrical Engineering Reference Book, 2004
5. Siemens Aklengesel, Chart Electrical Engineering Hand Book, 1987
6. S.V.Nadkarni, Modern Arc Welding Technology 2E (English) 01 Edition Oxford-IBH Publisher, 2005.

WE 102: WELDING PROCESSES –I

OBJECTIVES:

To impart a sound understanding of the principles of different fusion welding processes.

To study the process variables of different fusion welding processes and their effects on weld quality.

Welding history- Welding applications in use- Classification of welding processes as per ASME/ AWS / abbreviations of processes as per ISO 4063: arc phenomena, arc blow, manual metal arc welding, ingredients and function of flux covering, different types of electrodes and their applications, handling and storage of consumables; gas welding and cutting, flame characteristics, different kinds of flames and their areas of applications

Gas tungsten arc welding, electrode polarity, shielding gas, use of DC suppressers, arc starting and stopping, choice of filler metal composition, use of pulsed arc and GTA spot welding, other recent developments, applications;

Gas metal arc welding, considerations of electrode polarity, shielding gas and filler composition, nature and conditions of spray transfer, difficulties for thin sheet, dip transfer and CO_2 welding, flux cored and pulsed and synergic MIG welding.

Submerged arc welding: Advantages and limitations, process variables and their effects, significance of flux-metal combination, modern developments, narrow gap submerged arc welding, applications. Electroslag welding and Electro gas welding: Principles, process variables, advantages, limitations and applications.

Brazing & Soldering: Wetting and spreading characteristics, surface tension and contact angle concepts. Filling of horizontal and vertical capillary joints. Capillary dams. Role of flux and characteristics constituents of flux, grouping and applications, Joint design and fixturing for brazing. Hand soldering, flame soldering, furnace soldering, hot gas blanket soldering, torch brazing and furnace brazing. Applications of brazing and soldering, brazing and soldering defects.

REFERENCE BOOKS:

1. Welding Handbook (Welding Processes), Volume II, 9th Edition, American Welding Society (AWS), 2003.
2. Metals Hand Book (Welding and Brazing), Volume VI, 9th Edition, American Society for Metals, 2003.
3. Little, R.L., Welding and Welding Technology, Tata McGraw Hill, New Delhi, 1996.
4. S.V.Nadkarni, Modern Arc Welding Technology 2E (English) 01 Edition Oxford-IBH Publisher, 2005.
5. Parmar R. S., ‘Welding Processes and Technology’, Khanna Publishers, 2011.

WE 103: WELDING METALLURGY-I (FERROUS)

OBJECTIVES:

To study the welding metallurgy of ferrous materials and heat flow in welding.

To understand the problems encountered in welding of Carbon steels and Stainless Steels and remedial steps.

Introduction, Regions of a Fusion Weld, Fusion Zone, Solidification of Metals, Macroscopic Aspects of Weld Solidification, Microscopic Aspects of Weld Solidification, Unmixed Zone (UMZ), Partially Melted Zone (PMZ), Penetration Mechanism, Segregation Mechanism, Heat Affected Zone (HAZ), Recrystallization and Grain Growth, Allotropic Phase Transformations, Precipitation Reactions.

Heat flow in welding: temperature distribution in welding, heat flow equations, simple problems, metallurgical effects of heat flow in welding. Phase diagrams, Iron Carbon diagram, Time Temperature diagram, CCT diagrams for carbon and low alloy steels.

Weldability of Carbon Steels, HSLA steels, Q&T steels, Cr-Mo steels, Significance of carbon equivalent number, important problems encountered in welding of above steels and remedial steps, Preheat and Post heat requirements.

Weldability of Stainless Steels: stainless steel classification, Schaffler diagram, Delong diagram, WRC diagrams, problems associated with welding of austenitic stainless steel, ferritic stainless steel, martensitic stainless steel and duplex stainless steels.

Ferrite-to-Austenite transformation in austenitic stainless steel welds, Primary solidification modes, Mechanisms of ferrite formation, Prediction of Ferrite Content, Effect of Cooling Rate, Ferrite dissolution upon reheating. Austenite-to-Ferrite transformation in low-carbon, low-alloy steel welds, Microstructure development, Factors affecting microstructure,

REFERENCE BOOKS:

1. Sindo Kou, Welding metallurgy, 2nd edition, John Wiley & Sons, 2003
2. John C. Lippold, Damian J. Kotecki, Welding metallurgy and weldability of stainless steels,Wiley Publications, 2005.
3. R.S. Parmar, Welding Engineering and Technology, Khanna Publishers, 2013.
4. Raman Singh, Weld cracking in ferrous alloys, Woodhead Publishers, 2008.

WE 104: RESISTANCE AND SOLID STATE WELDING PROCESSES

OBJECTIVES:

To study the principles of Resistance welding and variants of Resistance welding.

To learn the principle of recently developed FSW and other solid state welding processes.

General principle- heat generation in resistance welding- Electrical Characteristics of Resistance welding; bulk resistance, Contact resistance, Total resistance, Shunting- Thermal Characteristics of Resistance Welding Heat Balance; Law of Thermal Similarity, Heat balance and Modified Heat Balance Theory- applications of resistance welding processes.

Spot welding: Principle, Spot welding sequence- Solidification in Resistance Spot Welding - variants of resistance spot welding; series welding, multiple spot welding, pulsation welding - welding variables- resistance welding equipment- spot welding electrode- joint design- variants of Resistance spot welding- application of Spot welding. Projection welding; Process details and working- applications of projection welding; Seam welding- Process details and working- variants of resistance seam welding; Roll spot and stitch welding, mash seam welding, foil butt seam welding- joint design, seam welding electrode, applications of seam welding.

Introduction, working principle, difference between friction welding and inertia welding, Operation steps, Metallurgy of friction welded joint, Fibre flow in friction welding, Defect formation, Process parameters, Friction welding of aluminium alloys, Friction welding of magnesium alloys, Friction welding of steel, Friction welding of titanium alloys, Friction welding of dissimilar metals, Thermal behaviour, Application

Ultrasonic welding: Principle of operation, Metallurgy of ultrasonic welds, welding equipment, welding variables, types of ultrasonic welds, materials ultrasonically welded, advantages, disadvantages and applications of ultrasonic welding. Diffusion welding: Principle, types, parameters, materials welded, advantages, limitations and applications of diffusion welding. Explosive welding: principle, mechanism, arrangements, explosives used, metallurgy of explosive welds, testing of explosive welded joints, advantages, limitations and applications of explosive welding.

Introduction-working principle, Operation steps, Metallurgy of FSW joint, Defect formation-Process parameters, Tool design, tool geometry and tool materials, Heat generation in FSW process, FSW of aluminium alloys, FSW of magnesium alloys- FSW of steel, FSW of titanium alloys, FSW of dissimilar metals, Thermal behaviour, Variants of FSW process

REFERENCE BOOKS:

1. Hongyan Zhang and Jacek Senkara, Resistance welding: Fundamentals and Applications, Second Edition, CRC Press, 2011.
2. Rajiv S. Mishra, Murray W. Mahoney, Friction Stir Welding and Processing, ASM International, 2007
3. O.P.Kanna, Welding Technology, Dhanpat Rai Publications, New Delhi, 2014.
4. R S Parmar, Welding Processes and Technology, Khanna Publishers, 2011.

WE 107 METAL JOINING LAB

OBJECTIVES:

To impart practical training to the students on various welding processes

To study the effect of parameters on weld quality

To get the hands on experience in SYSWELD and COMSOL software

1) Simple exercises to make butt, lap, fillet joints using SMAW, GMAW, FCAW and GTAW processes.
2) Studying the effect of electrode polarity on weld bead formation
3) Studying the effect of heat input on temperature distribution
4) Evaluating the performance of Power Source Characteristics
5) Studying the effect of shielding gases on weld quality
6) Studying the effect of welding parameters of various processes such as SMAW, GMAW, FCAW, GTAW on bead geometry
7) Studying the effect of friction welding parameters on weld quality
8) Studying the effect of friction stir welding parameters on weld quality
9) Studying the effect of electrical resistance welding parameters on weld nugget formation
10) Predicting the temperature distribution during fusion welding process by SYSWELD software
11) Predicting the residual stress distribution during fusion welding process by COMSOL software

WE 201: WELDING PROCESSES –II

OBJECTIVES:

To learn the principles of advanced fusion welding processes and their variants.

To understand the principles of allied welding processes such as underwater welding and Thermit welding and narrow gap welding.

Laser Beam Welding: Basics of Laser, types of Lasers, Gaseous systems: - Helium/neon and CO_2 Laser welding; Solid state Laser: Ruby and Neodymium doped yttrium aluminium garnet (Nd:YAG) Laser welding; Laser beam characteristics – Continuous Wave lasers, Pulsed Laser, High power diode lasers (HPDL) and Fibre Lasers; Principles of operation, effect of parameters on weld quality, advantages, and limitations, applications.

Electron beam welding: Fundamentals; Beam characteristics; Different degrees of vacuum, Heat generation and regulation, equipment details in typical set-up, Parameters and its effects on weld quality, advantages and disadvantages, applications, beam oscillation techniques, characteristics of electron beam welded joints

Advanced gas tungsten arc welding : Pulsed GTAW and high-frequency pulsed GTAW, magnetic arc oscillation welding - Square-wave AC GTAW and plasma - Cold and hot-wire feed additions in GTAW - Dual-gas GTAW and plasma welding – Multi cathode GTAW - A-TIG welding - Buried arc GTAW - High current GTAW - Process characteristics, advantages and applications of above techniques. Laser-enhanced GTAW and GTAW augmented laser welding.

Recent developments in the GMAW and FCAW processes: Pulsed GMAW - Pulsed flux-cored wire welding - Hybrid welding processes: GMAW/LBW - GMAW brazing - GMAW tandem welding - Narrow groove GMAW welding – Variants of GMAW : Surface Tension Transfer (STT) and Cold metal Transfer (CMT) - Process characteristics, advantages and applications of above techniques.

Allied Processes: Principle and concept of narrow gap welding, under water welding, thermit welding. Process characteristics, advantages and applications of above techniques. Principles and concepts of Induction brazing, Dip brazing, Resistance brazing, Vacuum brazing; Adhesive Bonding; High Frequency Welding; MIAB welding; Microwave joining.

REFERENCE BOOKS:

1. John Norrish. "Advanced welding processes Technologies and process control" Wood head Publishing and Maney Publishing. Cambridge, England. 2006.
2. Robert W. Messler, Jr. "Principles of Welding: Processes, Physics, Chemistry and Metallurgy" Wiley-Vch Verlag Gmbh & Co. NY. 2007.
3. Christopher Davis. "Laser Welding- Practical Guide". Jaico Publishing House. 1994.
4. Welding Handbook (Welding Processes), Volume II, 9th Edition, American Welding Society (AWS), 2003.
5. S.V.Nadkarni, Modern Arc Welding Technology, 1st Edition, Oxford-IBH Publisher, 2005.
6. Schwartz M.M. "Metals Joining Manual". McGraw Hill Books. 1979.

WE 202: WELDING METALLURGY-II (NON FERROUS)

OBJECTIVES:

To understand the welding metallurgy of non-ferrous materials

To impart a sound understanding of the phase diagrams

To understand the problems involved in welding of non-ferrous materials and precautions and welding procedure requirements

Classification of aluminium alloys – phase diagrams of aluminium alloys - various processes used for aluminium welding- problems involved in aluminium welding – precaution and welding procedure requirements- CCT diagrams of aluminium alloys, Age hardening behaviour of aluminium welds.

Classification of magnesium alloys – phase diagrams of magnesium alloys - various processes used for magnesium welding- problems involved in magnesium welding – precaution and welding procedure requirements- CCT diagrams of magnesium alloys, Microstructural characteristics of magnesium alloy welds.

Classification of copper alloys- influence of alloying elements in copper alloys - phase diagrams of copper alloys – various processes used for copper welding- problems involved in copper welding – precaution and welding procedure requirements - CCT diagrams of copper alloys.

Classification of titanium alloys – phase diagrams of titanium alloys - various processes used for titanium welding- problems involved in titanium welding – precaution and welding procedure requirements- CCT diagrams of titanium alloys, Weladability of titanium alloys, Microstructural features of titanium alloy welds.

Classification of nickel alloys – phase diagrams of nickel alloys - various processes used for nickel welding- problems involved in nickel welding – precaution and welding procedure requirements- CCT diagrams of nickel alloys. Weladability of nickel base alloys, Microstructural features of nickel base alloy welds.

REFERENCE BOOKS:

1. Linnert G.E, Welding Metallurgy, Vol I & II, 4th edition, American Welding Society, 1994.
2. Kenneth Easterling, Introduction of Physical Metallurgy of Welding, 2nd Edition, Butterworth - Heinman, 1992.
3. Saferian.D, The Metallurgy of Welding, Pergamon Press, 1985.
4. Sindo Kou, Welding metallurgy, 2nd edition, John Wiley & Sons, 2003

WE 203: DESIGN OF WELDMENTS

OBJECTIVES:

To understand the design of different types of welded joints.

To impart a sound understanding of the causes and effects of residual stresses.

Types of welded joints, butt joint, lap joint, T-joint, cruciform joint, corner joint and edge joint, fillet and groove welds. complete and partial joint penetration, classification and types of groove welds, single and double fillet welds, combined partial joint penetration groove and fillet welds, size of fillet and groove welds, weld symbols, standard system of representation of welded joints, brazed and soldered joints.

Design of Welded Joints, Joint design based on stresses in the structure; Joint design for structural elements such as bars, beams, plates, slabs, columns, trusses, plate girders, cylindrical shells and pressure vessels and pipe lines. Design for flanged connections, structural hollow sections and branch connections, weld joint design to control distortion and shrinkage, residual stresses and cracking.

Weld design for dynamic loading: Design for fluctuating and impact loading - dynamic behaviour of joints - stress concentrations - fatigue analysis - fatigue improvement techniques - permissible stress- life prediction. Principles and methods and practical approach for crack arresting.

Concept of stress intensity factor - LEFM and EPFM concepts - brittle fracture- transition temperature approach - fracture toughness testing, application of fracture mechanics to fatigue, weldments design for high temperature applications.

Welding residual stresses - causes, occurrence, effects and measurements - thermal and mechanical relieving; types of distortion - factors affecting distortion - distortion control methods - prediction - correction, jigs, fixtures and petitioners.

REFERENCE BOOKS:

1. Gray T. G. E. "Rational Welding Design", Butterworth's, 1982.
2. Bhattacharya M. "Weldment Design", Association of Engineers, 1991.
3. Radhakrishnan V. M. "Welding Technology and Design", Revised Second Ed., New Age International Publishers. 2008.
4. Hertzberg R. W. "Deformation and Fracture of Mechanics of Engineering Materials", John Wiley, 1996.
5. George E. Dieter. "Mechanical Metallurgy", Tata McGraw Hill, 2014.

WE 204: NON DESTRUCTIVE TESTING

OBJECTIVES:

To study the importance of Non Destructive Testing.

To learn the principles and applications of different methods of Non Destructive Testing.

Non Destructive Testing Versus Mechanical testing, Overview of the Non Destructive Testing Methods for the detection of manufacturing defects as well as material characterisation. Relative merits and limitations, Various physical characteristics of materials and their applications in NDT., Visual inspection – Unaided and aided.

Liquid Penetrant Testing - Principles, types and properties of liquid penetrants, developers, advantages and limitations of various methods, Testing Procedure, Interpretation of results. Magnetic Particle Testing- Theory of magnetism, inspection materials Magnetisation methods, Interpretation and evaluation of test indications, Principles and methods of demagnetization, Residual magnetism.

Thermography- Principles, Contact and non contact inspection methods, Techniques for applying liquid crystals, Advantages and limitation - infrared radiation and infrared detectors, Instrumentations and methods, applications. Eddy Current Testing-Generation of eddy currents, Properties of eddy currents, Eddy current sensing elements, Probes, Instrumentation, Types of arrangement, Applications, advantages, Limitations, Interpretation/Evaluation.

Ultrasonic Testing-Principle, Transducers, transmission and pulse-echo method, straight beam and angle beam, instrumentation, data representation, A/Scan, B-scan, C-scan. Phased Array Ultrasound, Time of Flight Diffraction. Acoustic Emission Technique –Principle, AE parameters, Applications.

Principle, interaction of X-Ray with matter, imaging, film and film less techniques, types and use of filters and screens, geometric factors, Inverse square, law, characteristics of films - graininess, density, speed, contrast, characteristic curves, Penetrameters, Exposure charts, Radiographic equivalence. Fluoroscopy- Xero-Radiography, Computed Radiography, Computed Tomography

REFERENCE BOOKS:

1. Baldev Raj, T.Jayakumar, M.Thavasimuthu "Practical Non-Destructive Testing", Narosa Publishing House, 2009.
2. Ravi Prakash, "Non-Destructive Testing Techniques", 1st revised edition, New Age International Publishers, 2010.
3. ASM Metals Handbook,"Non-Destructive Evaluation and Quality Control", American Society of Metals, Metals Park, Ohio, USA, Volume-17, 2007.
4. Paul E Mix, "Introduction to Non-destructive testing: a training guide", Wiley, 2 Edition New Jersey, 2005.

WE 207 WELDABILITY TESTING & EVALUATION LAB

OBJECTIVES:

To impart practical training to the students on various weldability testing

To study the Macro and Micro structure analysis of weldments

To get the hands on experience with non-destructive testing

1. Tensile properties evaluation of welded joints
2. Impact toughness properties evaluation of welded joints
3. Microhardness survey across the weld cross section
4. Bend Test (side and face) on welded joints
5. All weld metal properties evaluation
6. Macro and Micro structure analysis of weldments
7. Implant Testing for Hydrogen Induced cracking
8. Controlled Thermal Severity Test
9. Flaw Detection by Ultrasonic Testing
10. Flaw Detection by Magnetic Particle Inspection
11. Flaw Detection by Eddy Current Testing

LIST OF PROFESSIONAL ELECTIVES

1. Weldability Testing and Evaluation
2. Welding Codes, Standards, Safety & Quality
3. Residual stresses and distortion
4. Failure Analysis of Weldments
5. Life Assessment of Welded Structures
6. Mechanical Behaviour of Materials
7. Corrosion & Surface Engineering
8. Materials Characterization Techniques
9. Applied Probability and Statistics
10. Statistical Quality Control
11. Finite Element Analysis

WELDABILITY TESTING AND EVALUATION

OBJECTIVES:

To study the different weld cracks

To get thorough knowledge on various weldability testing methods

Weld defects and cracks: Arc welding defects: surface test, sub surface, acceptance level arc welding defects. Cracks: classifications - hot and cold cracks, orientation of weld cracks- weld metal crack, base metal crack- factor contributing, specific crack- cheveron, lamellar, reheat, stress corrosion cracking.

Fabrication Weldability Test : Fusion and Partially Melted Zone Hot-Cracking : Finger Test - Houldcroft and Battelle Hot-Crack Susceptibility Tests - Lehigh Restraint Test - Variable-Restraint (or Varestraint) Test - Murex Hot-Cracking Test - Root-Pass Crack Test - Keyhole-Slotted-Plate Test - Navy Circular Fillet Weldability (NCFW) – Circular Groove Cracking and Segmented Groove Tests – Circular Patch Test – Restrained Patch Test - Sigmajig Test. Heat-Affected Zone General Cold : Cracking Weldability Tests.

Hydrogen Cracking Testing **:** Implant Test - RPI Augmented Strain Cracking Test - Controlled-Thermal-Severity (CTS) Test - Lehigh Slot Weldability Test - Wedge Test - Tekken Test - Gapped-Bead-on-Plate or G-BOP Test. Reheat or Strain-Age Cracking Test **:** Compact Tension Test - Vinckier Test - Spiral Notch Test. Lamellar Tearing Tests **:** Lehigh Cantilever Lamellar Tearing Test - Tensile Lamellar Tearing Test .

Service Weldability Test: Weld Pool Shape Tests: Weld Testing : tensile test, nick break test, bend test, impact test, hardness test, fracture toughness test, fatigue test, creep test and corrosion test. Standards, testing procedures, and importances of the above tests.

Corrosion Tests: General Corrosion and its testing - Crevice Corrosion and its testing - Pitting Corrosion and its Testing - Intergranular Corrosion and its testing - Stress Corrosion and its Testing.

REFERENCE BOOKS:

1. S.V.Nadkarni, Modern Arc Welding Technology 2E (English) 01 Edition Oxford-IBH Publisher, 2005
2. R.S.Parmar, Welding Engineering & Technology, Khanna Publishers, New Delhi, 2013.
3. Robert W. Messler, Jr. “Principles of Welding: Processes, Physics, Chemistry and Metallurgy” Wiley-Vch Verlag Gmbh & Co. NY. 2004.
4. Radhakrishnan V. M. “Welding Technology and Design”, Revised Second Ed., New Age International Publishers. 2008.

WELDING CODES, STANDARDS, SAFETY & QUALITY

OBJECTIVES:

To impart a sound understanding of the welding codes and standards.

To know the health and safety requirements for each welding process.

To study the welding quality requirements.

Introduction to materials standards and testing of materials, consumables testing and qualification as per ASME/AWS/ ISO and National standards on welding requirements- Structural welding codes: Design requirements, allowable stress values, workmanship and inspection;

Process and product standards for manufacturing of pipe – welding procedure and welder qualifications, field welding and inspection. Pressure Vessel Fabrication: Design requirements fabrication methods, joint categories, welding and inspection, post weld heat treatment and hydrotesting.

Introduction to health and safety requirements Survey of safety and environmental aspects, risk assessment, Hazards of electric power, Electro-magnetic fields, Connecting of equipments, , Protective clothing and equipment, Health effects of grinding (vibration and dust), Cylinder storage and handling, Oxygen environment enrichment, Health and safety requirements for each welding processes, Ergonomics, Commonly occurring accidents & Prevention Methods; Special risks for automated processes.

Welding fume emission, Exposure limits (Maximum Allowable Concentration) MAC and UEL (Upper Exposure Limit) values, Ventilation filters and fume extraction (type of equipment and airflow), Determination of acceptable emissions, Tests for measuring emissions, Noise levels and ear protection, Standards and regulations; Problems with shielding gases, Radiation and eye protection

Quality control: Welding Quality requirements, Quality Assurance, Quality Plan, Quality Standards for Welding; Welding positions as per ASME/ AWS/ISO; Welder procedure specification (WPS), procedure qualification records (PQR) preparation, Welder Testing on different position of welding, Welder Certification

REFERENCES:

1. AWS D1.1 Structural Welding Code, 2011.
2. API 5L, 2009
3. API 1104, 2008
4. ASME Section VIII – Division 1, 2011.
5. ASME Section IX, 2011.
6. ASME Section II Part A and C, 2011.

<u>RESIDUAL STRESSES AND DISTORTION</u>

OBJECTIVES:

To know the general concepts and types of residual stresses and distortion.

To study the residual stress measurement

To study the effect of welding parameters on residual stresses and distortion.

General concepts of weld design, analysis of stresses in welded structures, permissible stresses, calculation of the size of welds for static and dynamic loading, location and orientation of welds in an assembly, residual stresses, types of residual stresses, control of residual stresses and measurement and calculation of residual stresses, Residual Stress Pattern, Causes of residual stress- -residual stresses in different joints- Methods of relieve stress.

Effect of welding parameter on heat distribution- calculation of peak temperatures- thermal cycles- cooling rate and solidification- Residual stresses and their distribution in welds- influence of residual stresses in static and dynamic loading

Residuals Stress measurement Methods: Deep-Hole Drilling, Incremental Centre-Hole Drilling, Neutron Diffraction, Contour, Ring Core, Sachs Boring, Slitting, Synchrotron Diffraction, Ultrasound and X-ray Diffraction.

Concept of distortion, types of distortion-longitudinal, transverse, angular, bowing, causes of distortion-heat input, restraint, inherent stresses in parent metal. Control of distortion-joint design, assembly procedure-pre-setting method: restrained method, welding procedure, welding process, type and size of electrode welding rod and wire, number of sequence of runs, size of deposit and welding position- welding current and welding speed, welding sequence and techniques- Other Techniques for Distortion Control.

Correction of distortion-Manual, use of press, local heating - hot shrinkage, use of heat strip, use of heat triangle. Distortion in cutting-factors causing distortion, examples of distortion in cutting. Distortion control techniques in cutting-immersion in water, flushing behind the cut, simultaneous cutting, wedging, step cutting, welding behind the cut, locking the scrap.

REFERENCES BOOKS:

1. Baldev Raj, V. Shankar,A.K. Bhaduri, Welding Technology for Engineers, Eds. Narora Publishing House, 3 rd Reprint,2009
2. V. M. Radhakrishnan, “Welding Technology and Design”, Revised Second Ed., New Age International Publishers, 2008
3. J.G. Hicks, A Guide to Designing Welds, Woodhead Publising Ltd., 2001.
4. The Science and Pratice of Welding, Vol-1 : Welding Science and Technology, 1996.
5. Robert W. Messler, Jr. “Principles of Welding: Processes, Physics, Chemistry and Metallurgy” Wiley-Vch Verlag Gmbh & Co. NY. 2004.

FAILURE ANALYSIS OF WELDMENTS

OBJECTIVES:

To impart a sound understanding of the different failures of weldments.

To study the case studies of failures in aerospace, shipbuilding and petroleum industries.

Types of failure, Causes and classification of failures, Classification and identification of various types of fracture. Stages of failure analysis: Site visit, Collect background information, Sample removal and testing protocol, Sample removal, Cleaning, and storage, Chemical analysis, Testing, Structural Integrity Assessment

Overview of fracture mechanics, characteristics of ductile and brittle fracture. Solidification cracking, Liquation cracking, Ductility-dip cracking, Reheat cracking, Strain-age cracking, Hydrogen-induced cracking

General concepts, fracture characteristics revealed by microscopy, factors affecting fatigue life Creep, stress rupture, elevated temperature fatigue, metallurgical instabilities, environmental induced failure, faulty heat treatments.

Factors influencing corrosion failures, overview of various types of corrosion stress corrosion cracking, sources, characteristics of stress corrosion cracking. Procedure for analyzing stress corrosion cracking, various types of hydrogen damage failures. Failure of weldments - reasons for failure procedure for weld failure analysis.

Some case studies of weld failures in aerospace, shipbuilding, petroleum industries, oil & gas, food processing, paper & pulp, pressure vessels & piping, power plants, etc.

REFERENCES BOOKS:

1. Case Histories in Failure Analysis, American Society for Metals (ASM), Ohio, 1989
2. Metals Hand Book, Failure Analysis and Prevention, Vol. 11, ASM, 2002.
3. S.T.Rolfe and J.M.Barsom, Fracture and Fatigue control in structures, Prentice Hall, 1992.
4. John C. Lippold, Welding Metallurgy and Weldability, John Wiley, 2014.
5. Elementary Engineering Fracture Mechanics, Broek.D, 3rd edn., Martinus Nijhoff Publishing , The Hague, 1982.

LIFE ASSESSMENT OF WELDED STRUCTURES

OBJECTIVES

To understand the different life assessment methods for welded structures.

To study the damage mechanisms in boilers and steam turbines.

Historical evolution and operation of power plants and petrochemical plants – general description, temperature, pressures and materials, failure in plants, 0 –definition of failure.

Weld metal toughness evaluation methods, significance of Ductile to Brittle Transition Temperature (DBTT), Linear Elastic Fracture Mechanics (LEFM) approach, Elastic Plastic Fracture Mechanics (EPFM) approach, temper embrittlement, hydrogen embrittlement.

Mechanisms, parametric extrapolation techniques – LM, OSD, MII, MB and MCM, design rules, cumulative damage, crack growth models, Remaining Life Assessment (RLA) methodology for bulk and localized damages.

High and low cycle fatigue, Coffin-Manson relationship, creep fatigue interaction, effect of hold time, frequency strain concentration, environment, rupture ductility, damage rules and life prediction, design rules for creep fatigue (CF), linear damage summation, failure mechanism maps, thermal fatigue (TF), thermal-mechanical fatigue (TMF), thermal-mechanical fatigue life prediction, crack growth in fatigue.

Materials, damage mechanisms and RLA of boiler tubes, header, steam pipes, roots, steam casings, valves and steam chests, steam turbines blades, high temperature bolts, Non-destructive assessment methods for extent of creep damage, replication, creep pipes, principles of micro-thermography, effective temperature determination by implanting diffusion couples, life prediction of petroleum pressure vessel materials for hydrogen service, materials of construction, integrity consideration of pressure vessel shells and cladding, improved alloys of RLA techniques, Arkhausen Noise.

REFERENCES BOOKS:

1. Viswanathan. R, “Damage Mechanisms and Life Assessment of High Temperature Components”, American Society for Metals, 1989.
2. Das. A. K. “Metallurgy of Failure Analysis”, Tata McGraw Hill, 1993.
3. Karl Hauffe, “Oxidation of Metals”, Plenum Press, 1981.
4. Viswanathan R. “Life Assessment and Improvement of Turbo-generators Rotors or Fossil Plants”, Pergamon Press, 1985.

MECHANICAL BEHAVIOUR OF MATERIALS

OBJECTIVES:

To study the tensile, hardness and toughness behaviour of materials.
To understand the factors affecting the fatigue and fracture behaviour.

Tensile behaviour: Engineering stress-strain Curve: Derivation of tensile strength, yield strength, ductility, modulus of elasticity, resilience and toughness from stress strain curves, comparison of stress-strain curves for different materials - true stress – true strain curve: true stress at maximum load, true fracture strain, true uniform strain, true lock necking strain - necking Criteria - Effect of strain rate, temperature and testing machine on flow properties - Notch tensile test - Tensile properties of steel - strengthening mechanisms - Strain hardening - Strain aging - Yield point phenomena.

Hardness & toughness behaviour: Hardness Measurements: Brinell hardness, Meyer hardness, Vickers hardness, Rockwell hardness and Microhardness - Relationship between hardness and the flow Curve - Hardness at elevated temperatures - Toughness measurements: Charpy, Izod and Instrumented Charpy - Transition Temprature Curves: significance, various criteria, metallurgical factors affecting the curves, Drop weight test, explosion crack starter test, Dynamic tear test and Robertson crack arrest test - Fracture Analysis Diagram.

Fatigue behaviour: Introduction: Stress cycles, S-N curves Goodman diagram, Soderberg diagram, Gerbar diagram - Cyclics stress strain Curve - Low cyle fatigue - Strain life Equation - Fatigue mechanisms - High cycle fatigue - Effect of following paramenters on Fatigue: Mean stress, stress concentration, specimen size, surface roughness, residual stress, microstructure and temperature. Fatigue crack propagation - Fatigue under combined stresses - Cumulative fatigue damage - Design for fatigue.

Fracture behaviour: Type of fracture in metals: ductile and brittle fracture - Theoretical cohesive strength of metals - Griffith theory - Metallographic aspects of fracture - Fractography - Notch effect - Concept of fracture curve - Fracture under Combined Stresses - Environment sensitive fracture: hydrogen embrittlement stress corrosion cracking - Fracture mechanics: strain energy release rate, stress intensity factor, crack deformation modes, fracture toughness testing, plastic zone size correction, crack opening displacement, J-integral and R-curve.

Time dependent mechanical behaviour: Creep curve - Stress rupture Test - Structural changes during creep - Mechanisms of creep deformation - Deformation mechanisms maps - Activation energy for steady state creep - Fracture at elevated temperature - Introduction to high temperature alloys - Predication of long time properties - Creep under combined stresses - Creep- Fatigue Interaction.

REFERENCE BOOKS:

1. George E.Dieter, "Mechanical Metallurgy", Tata McGraw Hill, 2014
2. M.A.Meyers and K K.Chawla, Mechanical Metallurgy, Prentice Hall, 1992.
3. Hertzberg R.W, Deformation and Fracture Mechanics of Engineering Materials, 5th edition., John Wiley & Sons, Inc., New York,2012.
4. Thomas H. Courtney, Mechanical Behavoiur of Materials, McGraw Hill 2nd Edition, 2005.

CORROSION AND SURFACE ENGINEERING

OBJECTIVES:

To impart a sound understanding of the principles of different types of corrosion.

To study the corrosion testing techniques and procedures.

To study the corrosion of ferrous and non- ferrous materials.

To study the different methods to prevent corrosion.

Principles of direct and Electro chemical Corrosion, Hydrogen evolution and Oxygen absorption mechanisms – Galvanic corrosion, Galvanic series-specific types of corrosion such as uniform, Pitting, Intergranular, Cavitations, Crevice Fretting, Erosion, and Stress Corrosion –Factors influencing corrosion

Corrosion testing techniques and procedures- Prevention of Corrosion-Design against corrosion –Modifications of corrosive environment –Inhibitors – Cathodic Protection –Protective surface coatings.

Corrosion of steels, stainless steel, Aluminum alloys, copper alloys, Nickel and Titanium alloys-corrosion of Polymers, Ceramics and Composite materials.

Diffusion coatings –Electro and Electroless Plating –Hot dip coating –Hard facing, Cladding, and over laying -Metal spraying, Flame and Arc processes- Conversion coating –Selection of coating for wear and corrosion resistance.

Laser and Electron Beam hardening –Effect of process variables such as power and scan speed - Physical vapor deposition, Thermal evaporation, Arc vaporization, Sputtering, Ion plating - Chemical vapor deposition – Proprieties and applications of thin coatings.

REFERENCE BOOKS:

1. Fontana. G., “Corrosion Engineering”, McGraw Hill, 2011.
2. Kameth G.Budinski, “Surface Engineering for Wear Resistance”, Prentice Hall, 2011.
3. Winston Revie.R. Uhlig, Corrosion, Hand Book 2nd edition. John Wiley, 2000.
4. Metals Hand Book –Vol. 5, Surface Engineering, ASM, 1996.

MATERIALS CHARACTERISATION TECHNIQUES

OBJECTIVES:

To impart a sound understanding of the principles of different materials characterisation techniques.

To study the principles and applications of electron Microscopy and thermal analysis techniques.

Optical Metallography - Macro examination, principle and working of optical microscope, specimen preparation, optical properties - numerical aperture, resolving power, depth of focus, depth of field, aberrations in optical microscopes and their remedial measures, different microscopic techniques-dark field microscopy, phase-contrast microscopy, polarized light microscopy, interference microscopy, high temperature microscopy; quantitative metallography.

Characteristic spectrum – Bragg's law – Diffraction methods – Laue, rotating crystal and powder methods. Intensity of diffracted beams – structure factor calculations.

Optical And X-Ray Spectroscopy: Optical emission spectroscopy, X-ray fluorescence spectroscopy - principle, equipment and applications. Diffractometer – general feature and optics – proportional scintillating and Geiger counters. X-ray diffraction application in the determination of crystal structure, lattice parameter and residual stress – quantitative phase estimation.

Techniques Of Electron Microscopy- Electron specimen interactions, electron optical instruments, transmission electron microscope - specimen preparation, imaging modes, applications, selected area diffraction, scanning electron microscope - operating modes and applications, electron probe microanalyser-qualitative and quantitative analysis, vacuum systems for electron microscopy, Scanning probe microscopy, atomic force microscopy, field ion microscopy - principle, instrumentation and applications.

Surface Chemical Analysis Techniques & Thermal Analysis Techniques - Auger Electron Spectroscopy–principle, instrumentation and applications in metallurgy; X-ray photoelectron spectroscopy - principle, instrumentation and applications; secondary ion mass spectroscopy/ion microprobe - principle, instrumentation and applications. Differential thermal analysis, differential scanning calorimetry and thermo-gravimetric analysis - principles, instrumentation, results interpretation.

REFERENCES BOOKS:

1. Angelo P C, "Materials Characterization", Reed Elsevier India Pvt Ltd, 2013.
2. Phillips V A, "Modern Metallographic Techniques and their Applications", Wiley Eastern, 2001.
3. Cullity B D., Stock S R "Elements of X-ray Diffraction", Prentice Hall, Inc 2001.
4. Hebbar K R, "Basics of X-Ray Diffraction and its Applications", I.K. International Publishing House, New Delhi, 2007.

APPLIED PROBABILITY & STATISTICS

OBJECTIVES:

To understand the probability theory and testing of hypothesis.

To study the concepts of experimental design and non-parametric test.

Introduction to probability theory – Random variable – Probability density and distribution functions – Standard distributions: Geometric, Hypergeometric, Binomial, Poisson, Normal, Log-Normal, Exponential, Gamma, Beta and Weibull distributions – Applications – Baye's Theorem – Chebysev's Theorem.

Sampling distributions of statistical parameters – Standard error – central limit theorem – t, F and Chi-square distributions - Estimation – Point estimation - Interval estimation for population means, standard deviation, proportion, difference in mean, ratio of standard deviations, proportions - Maximum likelihood estimation, least square estimation and bayesian estimation.

Testing of Hypothesis - Parametric test – small samples – Tests concerning proportion, means, standard deviations – Test based on Chi-square, goodness of fit and test of independence.

Non-parametric test – run test, sign test, U-test, H-test and kolmogorov-Smirnov (k-s) test – spearmen rank correlation coefficient test.

Experimental designs – completely randomised blocks– Latin square – Analysis of variance – Methods for one, two factor models, concepts of factorial design, fractional factorial design, response surface methods and designs.

REFERENCE BOOKS:

1. Irwin Miller & John Freund. E., Probability and Statistics for Engineers, , PHI, 2001.
2. Montgomery D.C & Runger G.C., Applied Statistics and Probability for Engineers, John Wiley and Sons, USA, 1994.
3. Bowker and Libermann, Engineering Statistics, , Prentice Hall of India (PHI), 1990.
4. Richard Levin.I., Statistics for Management, PHI, 1988.
5. Ronald E. Walpole, Introduction to Statistics, Macmillan Inc., New York, 1982.
6. Walter Rosenkorantz. A Introduction to Probability and Statistics for Engineers and Scientists, McGraw Hill, 1997.

STATISTICAL QUALITY CONTROL

OBJECTIVES:

To study the concepts of quality control.

To impart a sound understanding of the process control charts and special control charts.

To understand the concepts of reliability engineering.

Introduction - Management Aspects of Quality Improvement - quality planning; quality control; quality assurance; quality control and improvement, quality audit; vendor quality assurance, quality loss function; PDCA cycle; approaches and philosophies of Juran, Deming and Feigenbaum in quality management; Taguchi's methodology for the robust parameter design (RPD).

Statistical Process Control: Control charts for attributes and count of defects- p chart, np chart, c chart, u chart and stabilized p chart.
Chance and assignable causes of process variation, statistical basis of the control chart, control charts for variables- X chart, M chart, R chart, σ chart, u chart and stabilized p chart.

Special control charts- Group control chart, sloping control chart, moving averages and moving ranges control charts, coefficient of variation control chart and cumulative sum control chart. Warning and modified control limits, control chart for individual measurements, multi-vari chart, X - chart with a linear trend, chart for moving averages and ranges, cumulative-sum and exponentially weighted moving average control charts.

SAMPLING CONCEPTS: Introduction, Types of sampling plans-single, double, multiple, and sequential sampling plans, OC curves, Guidelines for using acceptance sampling, Acceptance sampling procedures and their applications; single-sampling plans for attributes ASN, ATI, AOQ curves - Lot-by-Lot acceptance sampling plans for attributes - skip-lot, Acceptance sampling for variables- Different criteria- IS 2500 Part II- Continuous sampling plan.

Reliability Engineering: Failure data analysis and life testing- Reliability parameters- Reliability models- Reliability evaluation methods- Weibull analysis- System reliability with components in series, parallel and mixed configuration- Active, partial and stand by redundancy- Availability and Maintainability concepts, Reliability centered maintenance -FTA, FMECA.

REFERENCE BOOKS:

1. Montgomery D.C., Introduction to Statistical Quality Control, John Wiley, 2016.
2. Gupta R.C., Statistical Quality Control, Khanna Publishers, New Delhi, 2014.
3. Faigenbaum A.V., Total Quality Control, Mc Graw-Hill., 2004.
4. Grant E.L., Statistical Quality Control, McGraw-Hill., 1998.

FINITE ELEMENT ANALYSIS

OBJECTIVES:

To study the basic concepts of FEM and applications of FEM in welding.

To impart a sound understanding of the one dimentional problem.

Historical Background – Basic concepts of FEM -Boundary conditions-Fundamentals of stress-strain relationships, Strain Vs Displacement relations-Temperature effects, Weighted residual methods – Introduction to variational formulation :Ritz method –Galerkin method – Solution of algebraic equations- Gaussian elimination- Significance and applications of FEM. .

One dimensional problems, Finite element modeling- Coordinates and shape functions-Interpolation-Derivation and assembly of finite element equations- Potential energy approach-Assembly of global stiffness matrix and load vector- Treatment of Boundary conditions-Quadratic shape functions- Example problems.

Constant strain triangular element- axisymmetric solids subjected to axisymmetric loads- two dimensional isoparametric elements-numerical integration– Poissons and Laplaces equation – Element Matrices and Vectors –Lagrangian Interpolation Polynomials- Illustrative examples.

Applications in welding: Data acquisition in Lab view, Incorporation of latent heat- Transient analysis, Time stepping procedure-Predication of grain structure- Models for Welding heat sources- Double ellipsoidal model, Gaussian surface model.

Computer Implementations: An overview of commercial packages- Preprocess- Mesh generation, Adapative meshing, boundary conditions- Input of data- Material properties-Updating the values- remeshing- Post processing- Validation- One dimensional heat conduction: Simple heat transfer problems

REFERENCE BOOKS:

1. Segerline L.J., “Applied Finite Element Analysis”, John Wiley, 1985.
2. Rao. S.S., “Finite Element Method in Engineering”, Pergamon Press, 1996.
3. Chandrupatla and Belagundu, “Finite Elements in Engineering”, PHI, 2001.
4. John A. Goldak, Mehdi Akhlaghi, “Computational Welding Mechanics”,Springer, 2011.
5. Cook, Rober Davis etal., “Concepts and Applications of Finite Element Analysis”, John Wiley and Sons, 2001.
6. Buchaman. G.R., Schaum’s “Outline of Finite Element Analysis”, McGraw-Hill Company, 1994.

LIST OF OPEN ELECTIVES

1. Joining of Advanced Materials
2. Automation in Welding
3. Repair welding and Reclamation
4.
5. Total Quality Management
6. Optimization Techniques
7. Computer Integrated Manufacturing systems
8. Manufacturing Management
9. Process Modelling & Application

JOINING OF ADVANCED MATERIALS

OBJECTIVES:

To study the welding of advanced materials such as composites, ceramics, glasses etc.

To know the need for joining of dissimilar material.

Introduction - options for joining composites - joining of organic (polymer) matrix composites - joining of metal-matrix composites - joining of ceramic-matrix composites - joining carbon, graphite, or carbon-carbon composites - achieving maximum joint integrity between composites.

Basic joining for ceramics and glasses - mechanical joining of ceramics - adhesive bonding, brazing, welding and soldering of ceramics - other methods for joining ceramics to ceramics - welding and fusing of glasses - cementing and adhesive bonding of glasses - soldering of glasses and solder glasses.

The challenges of joining polymeric materials - joining of thermosetting polymers - joining of thermoplastic polymers - joining elastomeric polymers or elastomers - joining structural or rigid plastic foams - joining dissimilar polymers.

Joining of electronic materials - Joining of magnetic materials: processes used, joint design, precautions required, problems encountered, remedial steps to be taken, Testing and evaluation of joint qualities.

Need for joining dissimilar materials - joining metals to ceramics - joining metals to glasses - joining of metals to polymers - joining of metals to composites - joining of ceramics to polymers - joining of ceramics to composites.

REFERENCE BOOKS:

1. Messler, Warren Savage, "Joining of Advanced Materials", Butterworth-Heinemann publications, 1993.
2. Welding Handbook (Welding Processes), Volume II, 9th Edition, American Welding Society (AWS), 2003 .
3. Matthews, F.L., Joining Fibre-Reinforced Plastics, London: Elsevier Applied Science,1987.
4. Schwartz, Mel M., Ceramic Joining, Metals Park, Ohio: ASM International, 2003.

AUTOMATION IN WELDING

OBJECTIVES

To impart a sound understanding of the mechanisation in welding.

To study the importance of robots in welding.

Layout of production line , Jigs, fixtures and positioners (types, applications, advantages, special precautions) Roller beads, manipulators Operational environment; Cables, electrical connections, and special precaution Auxiliary equipment (for fit up, movement, backing gas devices, flow meters etc) Joint fit up Tack welding (specific cares, distribution, length and their removal)Equipment for preheat, post heat, and other heat treatments, also temperature control including furnace and local heat treatment

Automated devices for welded structures**-** Pre assembly and tacking by welding distortion by welding and its prevention tolerances welded structure and the concept of automated devices complexity of devices for pre assembly and mechanization/automation in welding.

Mechanisation in welding: Mechanisation of flat / circular joints thin / thick sheets (Resistance weld/arc weld) mechanization of I beams (arc welding) longitudinal circumferential SA welding (roller blocks, column booms, flux supports) circular / spherical welding joints (rotating tables positioners) manufacture of welding longitudinal welded pipes by induction, GTAW, plasma and SA welding aspiral welded pipes.

Mechanisation of pipes and tubes - Butt welding, GTAW orbital welding of thin and thick Members; MIG/MAG orbital welding induction pressure welding, flash butt welding, tube-tube-plate welding - Automation in welding. Concept of automation lines **-** The tolerances and welding procedures and quality, auxillary equipment (fixture, transport, electrical, pneumatic, hydraulic) welding procedures for automation. Automatic lines for welding, automation of track wheels, automation of pipe's spiral welding.

Robotics in welding - The concept of robotics, the robot design and its applications for welding, welding procedures adequate for robotics, programming of robot's welding tolerances of assemblies for robot welding, auxillary devices for robot welding, new generation of welding robots, self alignment by current arc variation, light spot leading system.

REFERENCE BOOKS:

1. Kozyrev, "Industrial Robots Handbook", Mir Publishers, Moscow, 2011.
2. "The Procedure Handbook for Arc Welding", Lincoln Electric. USA, 2012.
3. Welding Handbook, Vol. 3, 9^{th} edn., American Welding Society, 2003.
4. Proceedings of the International Conference on Assembly Automation, British Welding Institute, 1981.
5. A.C.Davies, The Science and Practice of Welding, Vol-2 Cambridge University Press, 1996.

REPAIR WELDING & RECLAMATION

OBJECTIVES:

To impart a sound understanding of the different aspects of repair welding.

To study the hardfacing and cladding by using different arc welding processes.

Engineering aspects of repair, aspects to be considered for repair welding, techno-economics, repair welding procedures for components made of steel casting and cast iron, full-mould process, AWA bath tub test for cast iron repair, special procedures to avoid post-repair stress relief heat treatment, half bead, temper bead techniques, usage of Ni base filler metals.

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

Types of wear, wear resistant materials, selection of materials for various wear applications, reclamation surfacing techniques. Selection of welding processes for reclamation.

Integrating repair/maintenance into on-going operation, radiation protection, steam generators repair, plugging.

Hardfacing, Cladding, Overlaying by shielded metal arc welding, gas metal arc welding, flux cored arc welding, gas tungsten arc welding, submerged arc welding, gas welding, plasma transferred arc welding, laser welding; consumables for weld surfacing, dilution measurement, microstructural features, Applications.

REFERENCES BOOKS:

1. "Recommended Practice for Repair Welding and Fabrication Welding of Steel Casting", Steel Foundry Research Foundation, 1981.
2. Nagendra Reddy A., "Maintenance Welding Made Easy", Jaico Publishing House, 1997.
3. Lim Cottrel C., The Welding Institute, "Welding Cast Irons", 1991.
4. S. S. Peate. "Weld Surfacing and Hardfacing", The Welding Institute, 1987.

TOTAL QUALITY MANAGEMENT

OBJECTIVES:

To study the concepts of TQM and quality function deployment.

To impart a sound understanding of the process control charts and special control charts.

Concepts of TQM – Deming, Crosby and Juran's Philosophies – Quality system – ISO 9000 Quality system standards- Company certification as per ISO 3834, Welding co-ordinating personals requirements as per ISO -14731 / ISO 9606 ,Types of weld imperfections according to ISO 6520 standards. Acceptance criteria (e.g. ISO 5817, ISO 10042, ISO 13919, ISO 9013, ISO 17635)- Quality costs, Seven tools for Quality Control, Seven tools for Quality management, Quality Function Deployment (QFD).

Statistical Process Control: Control charts for attributes and count of defects – p chart, np chart, c chart, u chart and stabilized p chart. Control charts for variables – X chart, Me chart, M chart, R chart, σ chart – process capabilities studies (C_p and C_{pk})– Modified control charts.

Special control charts – Group control chart, sloping control chart, moving averages and moving ranges control charts, coefficient of variation control chart and cumulative sum control chart.

Acceptance sampling plans for attributes: Concepts – OC curves – single, double, multiple and sequential sampling plans – Acceptance Rectification plan – ATI and ASN concepts – LTPD sampling plan, switching rules for normal, tightened and reduced inspection – IS 2500 part I – Acceptance sampling plans for variables – Different criteria - IS 2500 Part II – Continuous sampling plan.

Reliability Engineering: Failure data analysis and life testing – Reliability parameters – Reliability models – Reliability evaluation methods – Weibull analysis – System reliability with components in series, parallel and mixed configuration – Active, partial and stand by redundancy – Availability and Maintainability concepts. Reliability centered maintenance – FTA, FMECA.

REFERENCE BOOKS:

1. Montgomery D.C., Introduction to Statistical Quality Control, John Wiley, 2016.
2. Gupta R.C., Statistical Quality Control, Khanna Publishers, New Delhi, 2014.
3. Faigenbaum A.V., Total Quality Control, Mc Graw-Hill., 2004.
4. Grant E.L., Statistical Quality Control, Mc Graw-Hill., 1998.
5. Halpern Siegmund, The Assurance Sciences, PHI, 1978.
6. Srinath L.S., Concepts in Reliability Engineering, Eastwest Press Ltd., 1991.
7. IS 397 Part I, II and III, IS 2500 Part I and II.

OPTIMIZATION TECHNIQUES

OBJECTIVES

To impart an in-depth knowledge on the different techniques for optimization.

UNIT I

Classical Optimization techniques: Unconstrained optimization – calculus of variations – Linear programming - Graphical and simplex methods – Duality

UNIT II

Non-linear Programming: Fibonacci method – Golden section method – Gradient descent method – Kuhn tucker conditions – method of Lagrangean multipliers – Quadratic programming – Wolfe's algorithm.

UNIT III

Integer linear programming: Gomory's cutting plane method – Stochastic linear programming – Geometric programming – Constrained and Unconstrained minimization problems.

UNIT IV

Dynamic programming – Multi stage decision processes – Principle of optimality- tabular method – computational procedure.

UNIT V

Non traditional optimization algorithms – Genetic algorithm – working principle-Difference and similarities between GA and traditional methods-Applications in manufacturing problems- Neural network-Simulated annealing approach.

Text Books:

1. Optimisation for Engineering Design, Kalyanamoy Deb., Eastern Economy Edition, Prentice Hall of India, 1998.
2. Optimisation Theory and Applications, Rao. S. S, Wiley Eastern Limited, 1995

Reference Books:

1. Globally Optimum Design, Wild D. T., John Wiley & Sons, New Work, 1978
2. Mechanical Design Synthesis with Optimization Applications, Johnson. C. Ray, Von Nostrand, Reinhold Company, 1971.

3. Johnson Ray C., Optimum Design for Mechanical Elements John Wiley and Sons, New York, 1990.
4. GoldbergDE, Genetic Algorithms Search, Optimization and Machine, Barnen, Addison-Wesley, New York, 1989.

COMPUTER INTEGRATED MANUFACTURING SYSTEMS

OBJECTIVES:

To study the concepts, design and implementation of CIM.

To understand the concepts and implementation of Flexible Manufacturing System and Group Technology.

Introduction to Intelligent Manufacturing: System components, architecture and data flow, operation.
Introduction to CIM: An overview of CIM, significance, design and implementation – consideration – present status.

Robotics: Automation and Robotics – Physical configuration, joint motions – End effectors: Grippers and Tools – Robot kinematics – Robotic sensors – Robot vision – Robot programming – Robot cell design and control – Robot Applications: Material transfer and machine loading/ unloading, welding, spray coating, processing operations, assembly and inspection.

Flexible Manufacturing System (FMS): FMS components – types of flexibilities – Material Handling and storage system: AGV – types, guidance and routing, AS/RS – types, components and special features – Computers in FMS – FMS Layouts – Benefits of FMS.

Group Technology (GT): Part family – Parts classification and coding – Machine cell formation – Algorithms based on similarity coefficients: Single Linkage Clustering Analysis (SLCA), Average Linkage Clustering (ALC) – Algorithms based on sorting of part – Machine Incidence Matrix: Production Flow Analysis (PFA) – Rank Order Clustering (ROC), Direct Clustering Algorithm (DCA), Cluster Identification Algorithm (CIA) – Cellular Layouts – Benefits of GT.

Automated Process Planning: Generative and Variant types of process planning – AI in process planning – Software - Computer- Aided Quality Control (CAQC): types of Co- Ordinate Measuring Machines (CMM) – Non-contact inspection methods – Flexible inspection system.

REFERENCE BOOKS:

1. Groover M.P, Automation, Production Systems and Computers Integrated Manufacturing, Prentice-Hall of India Pvt. Ltd., 2008
2. Radhakrishnan. P and Subramanyam. S., CAD/CAM/CIM, New Age International Pvt., Ltd., 2009.
3. Groover M.P, Mitchell Weiss, Roger N. Nagel and Nicolas G. Odery, Industrial Robotics: Technology Programming and Applications, McGraw-Hill Book Co., 1986.
4. Paul G. Ranky, Computer Integrated Manufacturing, Prentice Hall International, 1986
5. Deb., S.R., Robotics Technology and Flexible Automation, Tata McGraw-Hill Publishing Co. Ltd., 1996.
6. Yorem Koren, Computer Control of Manufacturing System, McGraw-Hill Book Co, Ltd.,
7. Andrew Kusiak, Intelligent Manufacturing System, Prentice Hall, 1990.

MANUFACTURING MANAGEMENT

OBJECTIVES:

To study the concepts of Qualitative and Quantitative methods.

To understand the concepts of Scheduling and assignment problems.

Manufacturing System: The concept of a system- Types of manufacturing system – The concept of a model – Model classification – model building – decision-making approaches. Forecasting: Qualitative and Quantitative methods - Moving averages, Exponential smoothing, – Single and double exponential smoothing - Single and multiple linear regression models Seasonal model

Methods for aggregate planning – Graphical and charting methods, Trial and error, Transportation method – Concepts of linear decision rule, Bowman's decision rule.

Inventory management system and models: EOQ model (without and with shortages)- Inventory models allowing price breaks, EPQ model - Inventory models allowing risk expected monetary value approach - Safety stock calculations, Single period inventory model – Inventory control systems – P,Q and S-s system – Selective Inventory control techniques.

Materials Requirements Planning (MRP) – Master production schedule, Bill of materials, MRP concepts, Lot Sizing – Lot-for-lot technique, EOQ approach, silver-meal approach, period order quantity approach, least unit cost approach, least total cost approach, wagner-whiten algorithm, part period balancing. Fundamental concepts of manufacturing resource planning (MRP II), Enterprise Resource planning (ERP), capacity planning and control. Principles of JIT production, Pull and push system, kanban, JIT purchasing, Supply chain management.

Scheduling and assignment problems. Notations and definitions – criteria, objective functions for scheduling – Job shop scheduling: Sequencing of n jobs through 1 machine – priority rules, n jobs through 2 machines – Jackson's rule. Flow shop scheduling – n jobs through 2 machines – Johnsons rule, n jobs through 3 / m machines – Johnsons rule, CDS algorithm, Palmer algorithm, Dannenbring algorithm, NEH algorithm, branch and bound algorithm, 2 jobs on m machines – graphical method – Multiproduct assignment problem - Index method, Hungarian method.

REFERENCE BOOKS:

1. Jay Heizer and Barry Render, Production and Operations Management, Prentice Hall Inc. fourth edition, 1996
2. Askin R.G & Standridge C.R., Modeling and Analysis of Manufacturing Systems, 11th edition, John Wiley, 2013
3. Monks J. G.,Operation Management : Theory & Problems, McGraw Hill, 1987
4. Chary; S.N., Production and Operations Management : Theory and Problems, TMH, New Delhi, 1990.
5. Chase R.B., Aquilano N.J and Jacobs R.R., Production and Operations Management, 8th edition, TMH, 1998

PROCESS MODELLING AND APPLICATION

OBJECTIVES:

To study the mathematical modelling and concepts.

To impart a sound understanding of the Software packages and Expert systems.

Introduction to modeling and process control: Mathematical modeling, physical simulation – advantages and limitations, process control and instrumentation – use of converters, gauges, thermocouples and other sensors.

Mathematical Concepts: Review of differential equations and numerical methods – introduction to FEM, FDM, CFD and heat transfer.

Software packages and Expert systems: Introduction to standard software packages like ANSYS, IDEAS, DEFORM. Introduction to expert systems, applications of expert systems in metallurgical processes, use of artificial intelligence, practical training in some software packages.

Computer applications in Physical Metallurgy: Use of computer for the construction of phase diagrams, alloy design and crystallography.

Computer applications in Process Metallurgy: Modeling of solidification, heat transfer, fluid flow, casting, welding and liquid metal treatment.

REFERENCE BOOKS:

1. Piwonka T.S., Vollen V., Katgerman L., "Modeling of Castings, Welding and Advanced Solidification Processes", 4th edition. TMS-AMIE., 1993.
2. Stocks G.M., Turchi P.E.A., "Alloy Modeling and Design", The Metals Society – AMIE, 1994.
3. Trivedi R., Sekhar J.A., Majumdar J., "Principles of Solidification and Materials Processing", Vol. 1 and 2., Oxford and IBH, 1989.
4. Cerjak H., 'Mathematical Modeling of Weld Phenomena". – 2, The Institute of Materials, 1997.