GUJARAT TECHNOLOGICAL UNIVERSITY

METALLURGY ENGINEERING (21)
HEAT TREATMENT
SUBJECT CODE: 2162107
B.E. 6th SEMESTER

Type of course: Engineering & Technology

Prerequisite: Physical Metallurgy-I

Rationale: Graduate of Metallurgy is expected to achieve material properties by different heat treatment processes. This course on Heat Treatment deals with understanding of principles and procedures for metals and alloys. Also, microstructure and property relations and achieving the desired properties by developing suitable structure by using proper heat treatment cycle.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks			Practical Marks			
				ESE (E)	PA (M)		ESE (V)		PA (I)	
					PA	ALA	ESE	OEP		
4	0	2	6	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	**Principles of heat treatment of steels:** Phase Transformation on heating, Forming of austenite, Kinetics of formation of austenite, Nucleation sites in eutectoid steels, Austenitic grain size, Grain growth, Determination of austenitic grain size, Importance of austenitic grain size, Method of plotting, Types of TTT diagram, Critical cooling rate, Effect of alloying elements on TTT diagram, Applications, Continuous cooling transformation diagram.	**10**	16
2	**Transformations**: Pearlitic transformation: Mechanism, Kinetics, Effect of alloying elements on transformation, Interlameller spacing, Bainitic transformation: Mechanism, Characteristics, Bainitic structure. Diffusionless transformation: Mechanism, Kinetics, Ms - Mf temperatures, Athermal & isothermal martensites, Effect of applied stress on transformation, Habit planes, Bain distortion model / crystallographic theory of martensitic transformation, Retained austenite, Martensitic transformation in non-ferrous systems such as Fe-Ni and Cu-Al systems.	**10**	17
3	**Heat treatment processes:** Annealing – Stress relieving, recrystallization annealing, full annealing, partial annealing, bright annealing, diffusion annealing, Spheroidizing, Normalizing, Hardening and Tempering, Hardening of typical steels, cast irons and non-ferrous alloys. Hardenability: Significance, Measurement Grossman method, Critical and ideal critical diameter, Jominy End Quench method, Use/Significance of Hardenability data, Effect of grain size and composition, Residual stresses, Quench cracking. ASTM A255-02: Hardneability, Factors affecting hardenability, Quenchants: Characteristics of quenchants, Different quenching media, Synthetic quenchants, Mechanism of quenching.	**16**	27
4	**Surface hardening of metals:**	**12**	20

	Principles involved in induction and flame hardening methods and application of selective hardening, Laser hardening, Case carburizing (solid, liquid and gaseous), Cyaniding, Carbonitriding, Nitriding, Plasma nitriding etc., Depth of penetration - its measurement and relation with time and temperature. Surface composites: importance and fabrication methods. Special heat treatment processes: Austempering, Martempering, Ausforming, Patenting, Sub-zero treatment etc., Thermo-Mechanical treatments.		
5	Heat treatment of alloy steels, tools and dies steels, stainless steels (with reference to carbide precipitation and sigma phase formation) and cast irons – specific examples, Heat treatment of aluminium alloys, titanium alloys and copper alloys, Concept of age-hardening. Design for heat treatment, Heat treatment furnaces- their temperature and atmosphere control, Defects in heat treated parts, Causes for the defects in heat-treated parts and remedies.	**12**	20

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	**30**	**30**	**10**	**10**	**05**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Heat Treatment (Principles and Techniques) by T. V. Rajan, C. P. Sharma and A.Sharma, PHI
2. Physical Metallurgy for Engineers by D. S. Clark and W. R. Varney, East-West Press
3. Introduction to Physical Metallurgy by S. H. Avner, Tata Mc-Graw Hill
4. Engineering Physical Metallurgy and Heat Treatment by Yu. M. Lakhtin, MIR Publishers
5. Material Science and Metallurgy for Engineers by V D Kodgire and S V Kodgire, Everest Publishing House
6. ASM, Metals Hand Book: Heat Treating, Vol. 4, 9th Ed., Metals Parks, Ohio
7. Heat Treatment of Metals, Singh, Vijendra, Standard Publishers distributors, Delhi.

Course Outcome:

After learning the course the students should be able to:

1. Understand transformation on heating, effect of alloying and grain size.
2. Interpret TTT and CCT Diagram.
3. Explain pearlitic, banitic and martensitic transformation kinetics and mechanism.
4. Differentiate heat treatment processes.
5. Explain hardenability and factors affecting it.
6. Choose suitable quenching media.
7. Explain different surface hardening and special heat treatment processes.
8. Explain different types of heat treatment processes in ferrous & non-ferrous metals with requisite UG level.
9. Design heat treatment process with least heat-treatment process.

List of Experiments:

1. Introduction to Heat treatment Processes.
2. Measurement of austenitic Grain size
3. To examine the effect of quenching media on hardening of steel.
4. To measure hardenability of given materials with jominy End quenched Test.
5. To study heat treatment and microstructure of En: 8 steel.

6. To study heat treatment and microstructure of En: 24 steel.
7. To study heat treatment and microstructure of En: 31 steel.
8. To study heat treatment and microstructure of tool steel.
9. To study different surface hardening treatments and special heat treatment processes.
10. To study defects occurring in heat treated part with their causes and remedies.

Design based Problems (DP)/Open Ended Problem:

1. Chart of different Microstructure of Plain Carbon Steel, Alloy Steel, Non Ferrous Alloys
2. TTT and CCT Diagram for different composition
3. Chart on different Heat Treatment Cycle.
4. Group discussion and Presentations on given topic
5. Any other problem decided by faculty based on syllabus.

Major Equipment:

1. Metallurgical Microscope
2. Polishing Machine
3. Sample Cutting and Grinding machine
4. Rough Belt Surfacer
5. Jominy End Quench Test Setup
6. Hardness Tester
7. Muffle Furnace
8. Image Analysis System

List of Open Source Software/learning website:

1. http://nptel.iitm.ac.in/
2. www.ocw.mit.edu

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.