Materials Science and Strength of Materials

1.1 Course Number: CH212

1.2 Contact Hours: 3-0-0 Credits: 9

1.3 Semester-offered: 2^{nd} Year-even

1.4 Prerequisite: Basic Physics, Physical Chemistry, Mathematics, and Thermodynamics

1.5 Syllabus Committee Member: Dr Deepak Dwivedi, Dr Amit Ranjan

2. Objective: The course objective is to understand how nature of atomic bonding influences the structure of the materials, and how structure and processing influence the properties of the materials. To understand perfect and imperfect crystalline structures and its measurement techniques. To understand inter-relationship between the microstructure and materials properties. To understand how phase diagram can be utilized to design the thermal processing steps to cause the materials to undergo phase transformations in a controlled manner to develop a desired microstructure and thereby examine the macroscale properties of the materials. To understand origins of mechanical behavior of the materials such as their stress-strain response, elasticity, plasticity, creep, viscoelasticity, and fatigue, and applying this understanding for engineering applications.

3. Course Content:

Unit wise distribution of contents

Unit	Topics	Sub-topic	Lectures
1	Structure of Material	Crystallographic description of the crystalline materials (indexing of planes, Direction and Symmetry), Characterization of materials using XRD	4
2	Defects and Diffusion	Defects: Imperfections in crystalline materials and alloys: Point, line, Surface and Volume defects, burger vector, Diffusion: Definition, Fick's First and Second Laws, Error function solution of Fick's second law, Atomistic mechanisms of diffusion, Steady and unsteady state diffusion	5
3	Mechanical Properties of Metals & Strengthening Mechanisms	Elastic behaviour of materials (Young's modulus, Poisson's ratio, bulk elastic properties), elastic strain energy, Tensile test, Engineering stress-strain curve, true stress strain curve (& relevancy for petroleum and chemical engineers), Necking, Hardness testing: Brinell, Rockwell, Vickers and Microhardness, Slip Systems, deformation of single crystal, Deformation of polycrystal, Deformation Twinning, Solid solution strengthening, work/strain hardening, Recovery, Recrystallization and Grain Growth	5

4	Modes of Failures and Testing Methods	Fracture: Definition, Types, Griffith theory, Stress Intensity Factor and Engineering applications, Ductile to Brittle Transition, Impact Testing: Brief Introduction of Izod and Charpy Test, Fatigue: Definition, Features, fatigue test, S-N curve, Bauschinger effect, woods concept of fatigue, Paris Law, Industrial ways to improve fatigue life, Fatigue's relevancy for petroleum and chemical engineers, Ductile to Brittle Transition, Creep: Definition, creep behaviour at constant load (primary, secondary and tertiary creep), Dorn equation, Creep mechanisms (Dislocation, Nabarro-Herring Creep, Coble creep), Constitutive equations, Deformation mechanism maps, Creep's relevancy for petroleum and chemical engineers and creep life estimation	6
5	Phases and Microstructures	Lever Rule, Microstructure Evolution, Invariant reactions [eutectic, eutectoid, peritectic, peritectoid], Gibbs phase rule	3
6. Ferrous Alloys & Phase Transformation			
6.1	Fe-C Phase diagram	Introduction and Illustration of eutectoid, hypoeutectoid and hypereutectoid steels	3
6.2	Phase Transformation	Thermodynamic driving force, homogeneous and heterogeneous nucleation, nucleation and growth rate and overall transformation, TTT diagram (C curve) and microstructure evolution (effect of cooling rate), Relevance of microstructures for upstream and downstream applications [industrial examples], TTT Diagrams for steels (eutectoid, hypoeutectoid and hypereutectoid steels, alloy steels and its relevance for upstream and downstream applications	6
6.3	Heat Treatment	Definition, Annealing, Normalizing, Tempering, Martempering and Martensitic Transformation, Quenching, Industrial applications of heat treatment (in context of upstream and downstream oil and gas sectors), Residual stress and quench cracks, Hardenability of steels: Effect of alloying elements	4
7. Non-Ferrous Alloys			
7.1	Phase Diagrams of Non-Ferrous Alloys	Solder alloy (Pb-Sn), Lead free solder alloy (Sn-Bi), Cu-Zn and Ni-Ti alloys	2
8	Manufacturing Practices	Rolling: Classifications (Hot and Cold), Problems and defects in Rolled Products Forging: Classifications, Forging Equipment and Forging defects Extrusion: Production of seamless pipes and tubes	2

4. **Readings**

4.1 Text Books:

1. Dieter GE, Bacon D. Mechanical metallurgy. New York: McGraw-hill; 1976 Dec.
2. William J. Callister and David G. Rethwisch, Materials Science and Engineering: An Introduction, 10^{th} Edition, Wiley

4.2 Reference Book

1. V. Raghavan, Materials Science and Engineering: A First Course, 6^{th} Edition, Prentice Hall India.

5. **Outcome of the Course:**

The students will be able to identify the periodic structures in crystalline materials and correlate it with the XRD data. The students will also be able to find the nature of the phase under given thermodynamic conditions and calculate their relative abundance in a solid solution from its given phase diagram. They can predict the microstructure and mechanical behavior in iron carbon and other binary systems from the given thermal history and phase diagram. Qualitatively draw the stress strain behavior of the materials given their microscopic details such as nature of bonding, structure etc. and design engineering materials for a given mechanical application.