Metallurgy for Non-Metallurgists: Steels, Heat Treatment and Failure Analysis

15 – 19 March 2027
Paris - Right Bank business hotel



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Introduction:

Metallurgy for non-metallurgists matters because pumps, shafts, bolts, vessels and exchanger tubes fail early when the wrong steel grade is bought, a heat treatment is skipped or a test certificate is read without understanding. This Core Concept course gives engineers and inspectors a working grasp of metal structure, the iron-carbon diagram, steel and alloy families, heat treatment, mechanical testing, damage mechanisms and fractography. Participants apply it to failed parts and material records and complete a Materials Selection and Failure Investigation Worksheet for a component from their own plant.

Course Objectives:

- Explain how crystal structure, grain size and phases on the iron-carbon diagram govern the strength and toughness of steel
- Distinguish carbon, low-alloy and stainless steels and the main copper, nickel, aluminium and titanium alloy groups from their composition and designation
- Specify annealing, normalising, quenching and tempering to reach a required hardness and toughness
- Interpret tensile, hardness and Charpy impact results on test certificates against the property values a design requires
- Select a material for a given temperature, pressure and corrosive service and record the reasons for the choice
- Recognise fatigue, creep and embrittlement from fracture surface evidence and plan a basic failure investigation

Target Audience:

- Mechanical and maintenance engineering staff who specify replacement parts and approve material substitutions
- Inspection and integrity staff who examine equipment in service and report cracking, distortion or damage
- QA/QC staff who review mill test certificates, heat treatment records and incoming material
- Process and project engineering staff who choose materials for new equipment and modifications
- Procurement and materials coordination staff who buy metal products to technical specifications

Course Outline:

Day 1: Metal Structure, Phases and the Iron-Carbon Diagram

- Metallic Bonding and Crystal Structures: BCC, FCC and HCP Lattices
- Grains, Grain Boundaries and Alloying: Solid Solutions and Second Phases
- Iron-Carbon Phase Diagram: Ferrite, Austenite, Cementite and Pearlite Fields
- Upper and Lower Critical Temperatures and Slow-Cooling Transformations
- Metallographic Specimen Preparation, Etching and Optical Microscope Examination

Day 2: Steel Families, Stainless Grades and Non-Ferrous Alloys

- Carbon Steel Classes by Carbon Content: Low, Medium and High Carbon Grades
- Low-Alloy Steels: Chromium, Molybdenum and Nickel Additions for Strength and Heat Resistance
- Stainless Steel Families: Austenitic, Ferritic, Martensitic, Duplex and Precipitation Hardening
- Non-Ferrous Overview: Copper, Nickel, Aluminium and Titanium Alloy Groups
- Mill Test Certificates, Grade Designations and Chemical Composition Tables

Day 3: Heat Treatment of Steel and Mechanical Property Testing

- Annealing and Normalising Cycles: Heating Temperature, Air or Furnace Cooling and Grain Refinement
- Quenching Media and Martensite Formation: Water, Oil, Polymer and Brine
- Tempering Temperature Selection and the Hardness-Toughness Trade-Off
- Tensile Stress-Strain Curve per ASTM E8/E8M and ISO 6892-1: Yield, UTS, Elongation and Reduction of Area
- Brinell, Rockwell and Vickers Hardness with Charpy Impact per ASTM E23 and ISO 148-1

Day 4: Damage Mechanisms and Materials Selection for Service

- Fatigue Crack Initiation, Growth and Beach Mark Evidence Under Cyclic Loading
- Creep Stages: Primary, Secondary and Tertiary Strain in High-Temperature Components
- Ductile-to-Brittle Transition and Low-Temperature Embrittlement in Ferritic Steels
- Hydrogen Embrittlement and Temper Embrittlement Susceptibility Factors
- Materials Selection Matrix for Temperature, Pressure and Corrosive Process Service

Day 5: Failure Analysis Case Studies and the Investigation Worksheet

- Failure Investigation Sequence: Evidence Preservation, Visual Survey and Sampling Plan
- Fractography: Ductile Dimples, Cleavage Facets and Fatigue Striations Under SEM
- Supporting Tests: EDS Composition Check, Hardness Traverse and Replica Metallography
- Case Study Review: Shaft, Bolt and Exchanger Tube Fractures from Several Sectors
- Materials Selection and Failure Investigation Worksheet Build and Peer Review

Skills You Will Gain:

- Microstructure Interpretation
- Steel Grade Identification
- Heat Treatment Specification
- Mechanical Test Data Review
- Material Certificate Verification
- Service Condition Materials Selection
- Damage Mechanism Recognition
- Fractography Basics

Why Attend This Course:

- Complete a Materials Selection and Failure Investigation Worksheet for a real component from your own plant
- Question supplier certificates and proposed material substitutions with confidence instead of accepting them unchecked
- Talk to metallurgists, laboratories and vendors in shared terms and brief them precisely when a part cracks or wears
- Compare material problems and fixes with peers from oil and gas, power, water, mining and manufacturing

Conclusion:

Most metal failures trace back to a structure, a heat treatment or a property that nobody checked against the service. The course moves from crystal structure and the iron-carbon diagram, through steel, stainless and non-ferrous families, to heat treatment and tensile, hardness and impact testing, then to fatigue, creep and embrittlement and service-based materials selection. The final day applies this to failed-part case studies and completes a Materials Selection and Failure Investigation Worksheet ready for the next material review or failure investigation.