SAULT COLLEGE OF APPLIED ARTS & TECHNOLOGY

SAULT STE. MARIE, ONTARIO

#7

COURSE OUTLINE

Course Title: METALLURGY

Code No*: MET 208

Program: MECHANICAL TECHNOLOGY

Semester: IV

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APPROVED

Chairperson Date

CALENDAR DESCRIPTION

METALLURGY	MET 208
Course Name	Course Number

PHILOSOPHY/GOALS;

Knowledge of metallurgy is essential to the Mechanical Technologist in today's industrial complex. Nearly all types of manufacturing depends upon the behaviour of metals and their alloys and upon the known skills in using them. It is not our aim to attempt to impart lifelong metallurgical skills, but certainly an appreciation of the complexity of the subject. It would be our hope that the successful graduate would know enough metallurgy to realize in the course of his encounters with metallurgical problems, that his own skills are limited and he needs to consult with a metallurgist.

METHOD OF ASSESSMENT (GRADING METHOD):

This course has two componets weighed in worth as shown:

Theory - 65-70%

Lab - 30-35%

TEXTBOOK(S):

Metallurgy - Johnson & Weeks, (5th edition)

The theory component covers three aspects of metallurgy:

Extractive
Physical
Mechanical

EXTRACTIVE METALLURGY; covers the early history of iron and steel, the ra materials and the equipment used in producing basic iron, the refining processes used in producing basic iron, the refining processes used to pro steel and various shaping and forming processes used to supply the require steel shapes in modern industry.

PHYSICAL AND MECHANICAL METALLURGY: covers the metallic state of pure met the mechanical properties of ferrous metals, the methods, theory and equif realted to testing metals, the theory of alloys and equilibrium diagrams, treatment for steel and surface treatments of ferrous metals.

(based on Metallurgy ^ Johnson and Weeks, 5th Ed.)

EXTRACTIVE METALLURGY;		Chapter	Pages
Topics;	1. Early History of Iron and Steel	1	1-12
	2. Producing Iron and Steel	2	13-27
	3. Refining into Steel	3	28-45
MECHANICAL METALLURGY:			
Topics:	4. Physical Metallurgy		74-87
	5. Testing of Metals & Mechanical Properties		87-104 105-11
PHYSICAL METALLURGY			
Topics:	6. Theory of Alloys		131-16
	7. Heat Treatment of Steel	9	165-20
	8. Surface Treatment of Steels	10	205-22

LABORATORY COMPONENT:

In the Laboratory, preparation of known specimens will lead to stud normalizing, nature structures study, and heat treatment. Hardness testi instruments and microscopes as well as specimen preparation equipment wil used.

TOPIC 1

SPECIFIC OBJECTIVES - EXTRACTIVE METALLURGY

Early History of Iron and Steel

The Student will be able to:

1. Give a historical account of the origins of iron and steel identifying by definition the composition of both the earlies furnace designs and damascus steel.

2. Describe the direct process for making wrought iron making reference to the role played by charcoal and the purpose serv by combustion and air in the production of sponge iron.

3. Describe the beginnings of production furnaces particularly it reference to the Catalon furnace and forge and the furnaces t evolved from the Catalon - (stuckoten or old high bloomery).

4. Describe the beginnings of steelmaking processes by making reference to:

    a) the nature and content of steel
    b) the need for steel
    c) the early carburizing process
    d) "Steeling" and Damascus blades", cementation, sheai
    e) wootz steel and the Huntsman process

TOPIC 2

PRODUCING OF IRON AND STEEL

The Student will be able to;

1- List the constituent materials which are consumed in the production of Iron and Steel.

2. List 5 common iron minerals in nature and show the chemical formula and the iron content of each.

3. List and describe the processes involved in beneficiating stony low grade ores like a) taconite and b) solerite.

4. Explain a) how coke is produced and list the by-products of the coke-making process,
b) the various purposes served by coke.

5. State the source of limestone, it's purpose in smelting and list the dissociation equation which shows the production of Cao (slaked lime).

6. List and describe the three kinds of scrap and state the purpose for using scrap in iron-making processes.

SMELTING

The Student will be able to:

1. Sketch and label a blast furnace cross section showing layers of iron ore, coke and limestone.

2. List the actions of the hot carbon monoxide gas as it passes through the furnace charge.

3. Describe the operation of a blast furnace paying particular attention to the double-bell hopper, the limestone reaction, the reduction of the silicarin ore and the production of the hot-air blast.

4. List the material requirements to make one ton of pig iron.

5. Explain the origin of the name "pig iron".

DIRECT REDUCTION PROCESSES

The Student will be able to:

1. Explain what "Direct Reduction" means and list the advantag of using such a process.

2. List the three general types of processes used for direct reduction of ore and write a brief explanation of each.

3. Describe the product which is produced by direct reduction methods and list the advantages and disadvantages of the product.

TOPIC 2

REFINING INTO STEEL

The Student will be able to

1. List the elements found in pig iron.
2. State the meaning of a) hot short steel
   b) cold short steel.
3. List the common steelmaking processes in the order of inventi
   and note briefly significant points about the process.

THE BASIC OXYGEN PROCESS

The Student will be able to:

1. List the advantages of the B.O.F. over the traditional open hearth process.
2. Sketch a diagram of the Basic Oxygen Furnace and briefly describe the procedure of operation.
3. Sketch the Bessemer Converter and note the difference betweer Bessemer and the B.O.F. in the manner in which oxygen is proc
4. List the main advantages of the Electric Arc. Furnace by ref< to kinds of products and unwanted addition of carbon.
5. Describe the workings of an induction furnace.

OPEN HEARTH

The Student will be able to:

1. Explain why the Open Hearth Furnace is so named.
2. Make and label a simple sketch of an Open Hearth Furnace wit it's checker chambers.
3. Describe the charge in an Open Hearth Furnace.
4. Compare the time to prepare a heat of steel by Open Hearth a B.O.F. processes.
5. Describe the crucible process and list the reasons that the process is still used.

INGOT PRODUCTION

The Student will be able to:

1. State the reason that molten steel is poured into ingot molds
2. List the components of an ingot mold and describe the functic of each and sketch a mold sitting on a mold car.
3. Describe the manner in which an ingot is stripped from it's ir by stripper crane.
4. List 7 major deficiencies or deficits found in ingots and bri describe each.

TYPES OF STEEL

The Student will be able to:

Describe and differentiate between:

a) killed steel
b) semi-killed steel
c) rimmed steel
d) capped steel

CON-CAST

The Student will be able to:

State the major advantages of Continuous Casting over alternc methods.

TOPIC 4

SPECIFIC OBJECTIVES - PHYSICAL METALLURGY

The Student will be able to:

1. Explain that strength together with plasticity is the combination of properties that makes metals so important in t mechanical and electrical field.

2. Note that behvaiour of metals in both plastic and elastic ran is important in design and in manufacture.

THE SOLID OR CRYSTALLINE STATE OF METALS

The Student will' be able to:

1. Define "crystal".

2. Draw a lattice structure in three dimensions showing 15 identifiable B.C.C. crystal patterns.

3. Sketch a) face-centered cubic crystal patterns;
   b) hexagonal closely packed crystal patterns.

4. List the common metals which exist as b.c.c. and/or f.c.c crystals.

5. Explain the special feature of iron which realted to it's ability to change from one crystal form to another during heating and cooling. State the name applied to such a change.

6. Explain that the properties of metals are dependent in a larc measure upon the type of space lattice dormed during soIdifi< and list the general properties that generally relate to
   a) face-centered lattice
   b) close-packed hexagonal lattice.

CLEAVAGE AND SLIP PLANES

The Student will be able to:

1. Explain that some of the most striking effects of the crysta pattern of atoms are the directional properties created by t' planes which have been formed by the orientation of the atom

2. Explain the significance and location of "cleavage planes".

3. State that "proof of crystallinity" is obtained when a mater such as a metal is ruptured.

4. Explain what happens to the atom groups when an attempt is ma* fracture metals of the plastic crystal state. Define - "slip planes".

MANNER OF CRYSTALLIZATION

The Student will be able to:

1. Using three sketches of liquid metals in the stages of solidification showing:

   a) nuclei present at the inception of freezing
   b) dendritic grain growth
   c) the convergence of crystals

2. Explain by referring to the stages in "13", how a metal solidifies, and why individual crystals do not share a common orientation.

3. Explain the reason that we believe explains the higher streng small grained metals over larger grained metals.

4. Make progressive sketches showing the formation of a crystal note and explain the proof of a snow crystal.

5. Note that regardless of the external shape of the metal cryst the internal shape of the crystal is the same if the metal is same.

6. Explain the difference between crystals and grains.

DEFORMATION OF METALS

The Student will be able to:

1. Make a sketch of a 100 x magnification of commercially pure i before deformation showing grain size and boundary. Make a similar sketch showing slight plastic deformation,

2. Explain what becomes of severely deformed metals.

3. Explain the changes in the physical properties of the metal a it has experienced some permanent deformation.
   Refer to: a) tensile strength
   b) yield point
   c) hardness
   d) scratch hardness (cutting strength)
   e) stiffness
   f) plasticity (formability)

4. Explain what happens to highly stressed and highly deformed materials in corrosive atmospheres.

WORK HARDENING

The Student will be able to:

1. Explain the phenomenon of "work hardening" according to the slip-interference theory.

RECRYSTALLIZATION

The Student will be able to:

2. Explain what happens to the structure of a highly stressed material if it's temperature is raised to above normal for a (annealing).

3. Explain the process called "stress relief".

4. Explain the phenomenon of "recrystallization" and list the advantages to be gained by causing a stressed and distorted crystal structure to recrystallize.

GRAIN GROWTH

The Student will be able to:

1. Explain what happens to the grains when work hardened materia is heated to a temperature above that of the lowest temperatu of recrystallization and held at that temperature for a time.

2. Explain why large grains as gained in long anneal campaigns a often desirable.

3. State the relationship between the amount of cold deformation and the resultant grain size after anneal.

GERMINATION

The Student will be able to:

1. Explain the meaning of the term "germination".

COLD CRYSTALLIZATION

The Student will be able to:

1. Explain the reasons that old belief that "metal sections ofte failed in service due to cold crystallization" has been disca

2. State the conditions under which grain growth will occur belo critical temperature range.

State how chain links and like parts not yet failed, but brit
from severe service can be somewhat restored to strenght. No
that when surface cracking has occurred annealing will not
strengthen or weld broken parts.

TOPIC 5

SPECIFIC OBJECTIVES - MECHANICAL PROPERTIES OF METALS

The Student will be able to:

1. Note that a thorough knowledge of the physical properties of metals is required by people in skilled trades to enable their do their jobs efficiently and effectively. The technologist-technician must know the specific properties to do his job.

2. Understand that strength combined with toughness, are characteristics making steel so valuable as the primary construction material.

3. List other factors and properties that allow certain material to be used in industry.

4. Note that metals can be cast into varied and intricate shapes and steels can be readily welded.

5. Given a steel product, described by it's similarity to benchir steel products, determine the range of it's carbon content.

6. Given a particular carbon content, provide (list) at least tw steel products that have that level of carbon.

7. Differentiate between "carbon steels" and "plain carbon steel

8. State the carbon range of steel.

9. State the purpose of modifying carbon content of steel.

10. State the carbon content and applications of

    a) low carbon steel
    b) medium carbon steel
    c) high carbon steel

MINOR CONSTITUENTS

The Student will be able to:

1. State the reason for adding or removing the following minor constituents in steel:

    a) mangonese
    b) silicon
    c) sulfur
    d) phosphorous
    e) copper
    f) lead
    g) oxides
    h) gases

SELECTION OF CARBON STEELS

The Student will be able to;

1. Define the following by carbon content, the possible resultar products and some of it's mechanical properties:

   a) ingot steel
   b) tin plate
   c) wire rivets & nails
   d) structural steel
   e) forging steel
   f) screw machine steel
   g) tool steels

MECHANICAL PROPERTIES

The Student will be able to:

1. Draw the curves of the following related to % carbon:

   a) hardness
   b) toughness
   c) tensile strength
   d) field strength

2. State why it is essential that a mechanical technician-technologist know the definitions of the various mechanical properties of metals.

3. Define clearly:
   a) strength
   b) plasticity
   c) tensile strength
   d) compressive strength
   e) fatigue strength
   f) yield strength

4. State clearly the meanings of the following words as they rel to metals performance:
   a) elasticity
   b) ductility
   c) malleability
   d) toughness
   e) brittleness

, 5. State the importance of the position of a metal on the electr chemical series to it's nature to corrode.

6. Explain "sacrificial action" and state how this principle is applied for the prevention of the corrosion of iron.

TOPIC 6_

SPECIFIC OBJECTIVES - THEORY OF ALLOYS

The Student wi11 be able to;

1. Using the cooling curves for a type I alloy system in which t percentage of one alloy is varied in steps of 20% from 0% to Construct the typical constitutional diagram of the type I sy

2. Draw the typical time-temperature cooling curves for alloys t form solid solutions, eutectic mixtures or eutectoid mixtures Explain why each curve is the shape shown.

3. Given a type I alloy system as defined by it's constitutional diagram (copper-nickel); explain what happens as an alloy ric in copper than nickel cools slowly from liquid to a solid.

4. Explain how cored structures occue in type I alloy systems.

5. Explain what "eutectic" means.

6. Given a type II alloy system as defined by it's constitutiona diagram, explain what happens as an alloy of 25% metal A, 75% metal B cools slowly from liquid to solid. Use the cadmi bismuth system as an example.

7. Given a type III alloy system as defined by it's constitution. diagram, explain what happens as an alloy of 25% metal A, and 75% metal B cools slowly from liquid to solid. Use the coppe silver system as an example.

8. Explain the importance of the formation of intermetallic comp< in industrial alloys. List the common ones.

9. Sketch the simplified iron carbon diagram and identify the different areas with the following labels:

   a) liquid solution
   b) liquid solution and solid solution
   c) iron
   d) and
   e) iron and Fe^C
   f) Fe_3C + Liquid
   g) iron + Fe

10. Define the Following:

   a) ferrite
   b) iron
   c) cementite
   d) iron carbide
   e) Cm
   f) pearlite
   g) austenite
   h) iron
   i) allotropy

Sketch the "steels portion" of the iron - iron earbide diagrc label completely.

State the temperatures at which the following solids form:

a) pearlite
b) pure iron

Describe the slow cooling of an eutectoid steel from it's austenite form.

Describe the slow cooling of a structural steel from it's austenite form.

Describe the slow cooling of a tool steel from it's austenite form.

Describe the slow heating to austenite from room temperature a eutectoid steel.

Explain what happens to an alloy containing more than 1.7% ca as it cools slowly from it's austenite form.

Describe crystal growth as a functional temperature.

Explain what happens to the characteristics of carbon steel a impurities are added.

TOPIC 7

SPECIFIC OBJECTIVES - HEAT TREATMENT OF STEEL

The Student will *be* able to:

1- Define "Heat Treatment" and state the objective of heat treatment.

2. Make a sketch of the iron carbon diagram and shade in areas showing the temperatures at which various heat treatments are conducted.

Use the following colour scheme:

Red - full annealing and hardening range
Yellow - normalizing range
Green - Spheroidizing range
Orange - Process annealing of cold worked steel

3. a) In point form, describe the procedure followed for normal heat treatment.
b) State why normalizing is done and to which kinds of steel products the procedure is applied.
c) Describe the origin of and heat treatment procedure for eggshell type structures in hypereutectoid steels.

ANNEALING

The Student will be able to

a) State why annealing is carried out.
b) Describe the general annealing process.
c) State the two basic types of structures obtained from annealing heat treatments and make sketches of each structure after being annealing for free machining.
d) Describe the annealing process suitable for each of the two types of annealing heat treatments mentioned in 4(c).
e) Explain how a spheroidization may be done in reduced time compared to normal/ as a result of fairly recent discover

ANNEALING OF COLD-WORKED STEEL

The Student will be able to

a) Explain what happens to the grains of metal when cold wor
b) Explain the general process for annealing cold-worked met-
c) Explain "bright annealing".

STRESS - RELIEF

The Student will be able to

a) Explain the sources of the causes of high residual stress
b) Explain how a part may be relieved of stress by heat treatment.

HARDENING OF CARBON STEELS

The Student will be able to:

1. a) State the three main requirements of steel for successful hardening by the quench-harden method,
   b) State the general procedures for quench-hardening.
   c) Explain the object of heating operation in the quench-hardening procedure.

2. Explain the significance of the AcCm line in the modified Iro Carbide diagram referred to in Objective 2; in terms of the formation of gamma iron,

3. a) State the purpose of the rapid cooling operation in harde
   b) In terms of temperatures, speed of cooling and metallurgy products, explain the formation of the brittle hardened material called martensite.
   c) Describe the appearance and physical properties of marten
   d) Explain why quenching is necessary in hardening,
   e) Sketch the time-temperature quenching curve for steel sho' a series of curves which lead to various heat treatment products including a successful quench to martensite*
   f) Define "retained austenite" by explaining it's formation.

QUENCHING MEDIA

The Student wi11 be able to:

1. a) List the names of the three kinds of steel as categorized the quenching media.
   b) Describe the three stages of liquid quenches.
   c) State the purpose of quenching in bring solutions.
   d) Explain why oil is used as a quenching medium.

HARDENING EFFECTS

The Student w i11 be able to:

1 a) Explain what is meant by shallow hardening.
   b) Explain the relationship between original grain size, heat treating temperature and time at temperature upon grain si
   c) State the reasons for warpage and cracking in heat treated steels.
   d) Explain the reason for the occurrence of a layer of soft material on the surface of hardened steel.
   e) Explain the occurrence of soft areas on the surface of hardened tools and dies.

TEMPERING

The Student will be able to:

12. a) State the operations involved in the general process of tempering,
    b) List the quantities present in a fully hardened steel before tempering.
    c) State reasons for tempering,
    d) Explain what happens to a fully hardened plain carbon steel as it:

        i) is heated to 93°C
        ii) is heated to 205°C
        iii) is heated to 260°C
        iv) is heated to 315°C

    e) Explain the effect of tempering upon hardness and tough
    f) Explain the effect of time in tempering.
    g) Explain the causes of volume changes in hardening and toughening.

TOPIC 8

SPECIFIC OBJECTIVE - SURFACE TREATMENT OF STEELS

CARBURIZING

The Student wi11 be able to;

1. State the general purpose and procedure used for carburizing surface.

2. Describe in detail, stating equipment used, time and temperat the processes:

    a) Pack Carburizing
    b) Gas Carburizing
    c) Liquid Carburizing (cyaniding)
    d) Chapmanizing
    e) Nitriding

3. Describe in detail, mention temperatures and equipment used f the processes:

    a) Flame Hardening
    b) Induction Hardening

4. State some of the reasons to explain why coatings are appliec metals.

5. Describe the following processes:

    a) Phosphate Coatings
    b) Surface Oxidation
    c) Metal Spray processes
    d) Hard facing processes
    e) Oxide Coatings