COURSE CODE: *MCE 203*

COURSE TITLE: *Engineering Materials*

NUMBER OF UNITS: *3 Units*

COURSE DURATION: *Three hours per week*

COURSE DETAILS:

Course Coordinator: **Dr. Engr. Olokode, O.S.** Ph D
Email: olokodeos@unaab.edu.ng
Office Location: **Room 4 PG School**
Other Lecturers: **None**

COURSE CONTENT:

Atomic and crystal structure. Metallic states. Defect in crystals, conductors, semi-conductor insulators and super-conductors. The relationship between structure and properties. Alloy theory application to industrial alloys- steel in particular. Simple phase diagram of alloys. Engineering properties – the control, hot and cold working, heat treatment, etc. creep, fatigue and fracture. Corrosion and corrosion control. Non-metallic- glass, rubber, concrete, plastics, wood and ceramics. Elastic and plastic deformations. Materials for cryogenic, corrosive media and nuclear applications.

COURSE REQUIREMENTS:

This is a compulsory course for all students in engineering. In view of this, students in the college of engineering are strongly advised to attend classes regularly and have a minimum of 75% attendance to be eligible to write the final examination.

READING LIST:

Materials Science and Engineering: An Introduction [Hardcover]
William D. Callister (Author), David G. Rethwisch

LECTURE NOTES

Metal and Metallic Materials

- Classifications & Specifications of Metallic Materials
- Major characteristics of metallic materials are crystallinity, conductivity to heat and electricity and relatively high strength & toughness.
- Classification: systematic arrangement or division of materials into group on the basis of some common characteristic
- Generally classified as ferrous and nonferrous
    - Ferrous materials-iron as the base metal,
        - range from plain carbon (>98% Fe) to high alloy steel (<50% alloying elements)
    - Nonferrous materials consist of the rest of the metals and alloys

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- Within each group of alloy, classification can be made according
  - (a) chemical composition, e.g. carbon content or alloys content in steels;
  - (b) finished method, e.g. hot rolled or cold rolled;
  - (c) product form, e.g. bar, plate, sheet, tubing, structural shape;
  - (d) method of production, e.g. cast, wrought alloys.

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- Designation: identification of each class by a number, letter, symbol, name or a combination. Normally based on chemical composition or mechanical properties.
- Example : Table 2.1 designation systems for steel
- System used by AISI & SAE: 4, or 5 digits which designate the alloy composition.
  - 1st two digits indicate Alloy system
  - Last two or three digits nominal carbon content in hundredths of a percent

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Table 2.1 Some AISI-SAE standard steel designations and corresponding UNS numbers

No.	Name	Example	UNS	C	Mn	Nominal composition (wt %)					
						P(max.)	S(max.)	Si	Ni	Cr	Other
Carbon steels											
10XX	Plain carbon	1015	G10150	0.15	0.45	0.04	0.05				
11XX	Free machining	1118	G11180	0.18	1.15	0.04	0.13				
15XX	Plain carbon	1524	G15240	0.24	1.35–1.65	0.04	0.05				
Manganese steels											
13XX	Mn	1335	G13350	0.35	1.75	0.035	0.04	0.25			
Molybdenum steels											
40XX	Mo 0.25	4027	G40270	0.27	0.8	0.035	0.04	0.3			0.25 Mo
44XX	Mo 0.52	4419	G44190	0.19	0.55	0.035	0.04	0.22	–	–	0.52 Mo
Chromium-molybdenum steels											
41XX	Cr Mo	4118	G41180	0.18	0.8	0.035	0.04	0.3	–	0.5	0.1 Mo
Nickel-chromium-molybdenum steels											
43XX	Ni Cr Mo	4320	G43200	0.20	0.55	0.035	0.04	0.3	1.8	0.5	0.25 Mo
86XX	Ni Cr Mo	8640	G86400	0.40	0.85	0.035	0.04	0.3	0.55	0.5	0.2 Mo
94BXX	Ni Cr Mo B	94B17	G94171	0.17	0.85	0.035	0.04	0.3	0.45	0.4	0.1 Mo, 0.0005Bmin

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- In most eng. application, selection of metallic is usually based on the following considerations:
  1) Product shape: a) sheet, strip, plate, (b) bar, rod, wire, (c) tubes, (d) forging (e) casting
  2) Mechanical properties-tensile, fatigue, hardness, creep,impact test
  3) Physical & chemical properties-specific gravity, thermal & electrical conductivity, thermal expansion
  4) Metallurgical consideration-anisotrophy of properties, hardenability of steel, grain size & consistency of properties
  5) Processing castability-castability, formability, machinability
  6) Sales appeal-color, luster
  7) Cost & availability

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- Design and selection for metals
  - One of the major issues for structural components is deflection under service load.
    - A function of the applied forces and geometry, and also stiffness of material.
    - Stiffness of material is difficult to change, either shape or the material has to be changed if order to achieve a large change in the stiffness of a component.

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- Load carrying capacity of component can be related to the yield strength, fatigue strength or creep strength depending on loading & service condition.
  - All are structure sensitive.
  - Changed by changing chemical composition of the alloy, method and condition of manufacturing, as well as heat treatment
  - Increasing the strength cause metal ductility & toughness to decrease which affects the performance of component.

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- Electrical & thermal conductivities
  - Thermal conductivity, K
    - Is measure of the rate at which heat is transferred through a material
  - Al & Cu- Manufacture of component where electrical conductivity is primary requirement
- Corrosion resistance & specific gravity limits the materials.

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- Manufacturing consideration
  - Majority of metallic components are wrought or cast
  - Wrought m/str:
    - usually stronger and more ductile than cast.
    - Available in many shapes & size tolerance
  - Hot worked products:
    - Tolerance are wider thus difficult for automatic machining
    - Poor surface quality, esp. in sheet/wire drawing
  - Cold worked product:
  - Narrow tolerance
  - Residual stress cause unpredictable size change during machining

Design for polymer

- Classifications of Polymers
- Polymer – low density, good thermal & electrical insulation, high resistance to most chemicals and ability to take colours and opacities.
- But unreinforced bulk polymer are mechanically weaker, lower elastic moduli & high thermal expansion coefficients.
- Improvement Reinforced variety of fibrous materials Composites (PMC).

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- Advantages : ease of manufacturing & versatility.
  - Can manufacture into complicated shapes in one step with little need for further processing or surface treatment.
  - Versatility : ability to produce accurate component, with excellent surface finish and attractive color, at low cost and high speed
- Application: automotive, electrical & electronic products, household appliance, toys, container, packaging, textiles
- Basic manufacturing processes for polymer parts are extrusion, molding, casting and forming of sheet.

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- Thermoset & thermoplastic
  - Differ in the degree of their inter-molecular bonding
  - Thermoplastic-litle cross bonding between polymer, soften when heated & harden when cooled
  - Thermoset-strong intermolecular bonding which prevents fully cured materials from softening when heated
- Rubber are similar to plastic in structure and the difference is largely based on the degree of extensibility or stretching.

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- Design consideration for polymer
  - Structural part/When the parts is to carry load
    - Should remember the strength and stiffness of plastics vary with temperature.
    - T_{room} data cannot be used in design calculation if the part will be used at other temp.
  - Long term properties cannot be predicted from short term prop. Eg. Creep behavior
  - Engineering plastics are britle (notched impact strength < 5.4 J/cm)
    - Avoid stress raiser

Design for ceramics

- Classification of Ceramic Materials
- Ceramics – inorganic compounds of one or more metals with a nonmetallic element. Eg Al_2O_3, SiC, Si_2N_3.
  - Crystal structure of ceramic are complex
    - They accommodate more than one element of widely different atomic size.
  - The interatomic forces generally alternate between ionic & covalent which leave few free electrons
    - usually heat & electrical insulators.
  - Strong ionic & covalent bonds give high hardness, stiffness & stability (thermal & hostile env.).

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- Structure:
- (1) Amorphous or glass-short range order, (2) crystalline (long range order) & (3) crystalline material bonded by glassy matrix.
- Clasiification:
  - Whitewares, glass, refractories, structural clay products & enamels.
- Characteristics:
  - Hard & brittleness,
  - low mechanical & thermal shock
  - High melting points
  - Thermal conductivities between metal & polymer

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- Design consideration for ceramics
  - Britle, low mechanical & thermal shock-need special consideration
  - Ratio between tensile strength, modulus of rupture & compressive strength ~ 1:2:10. In design, load ceramic parts in compression & avoid tensile loading
  - Sensitive to stress concentration
    - Avoid stress raiser during design.
  - Dimensional change take place during drying and firing, should be consider
  - Large flat surface can cause wrapping
  - Large changes in thickness of product can lead to nonuniform drying and cracking.
  - Dimensional tolerances should be generous to avoid machining

Design for composite

- Introduction
  - A composite material can be broadly defined as an assembly two or more chemically distinct material, having distinct interface between them and acting to produce desired set of properties
    - Composites – MMC, PMC & CMC.
  - The composite constituent divided into two
    - Matrix
    - Structural constituent / reinforcement

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- Properties / behavior depends on properties, size & distribution, volume fraction & shape of the constituents, & the nature and strength of bond between constituents.
- Mostly developed to improve mechanical properties i.e strength, stiffness, creep resistance & toughness.
- Three type of composite
  - (1) Dispersion-strengthened,
  - (2) Reinforcement – continuous & discontinuous
  - (3) Laminated (consist more than 2 layers bonded together).

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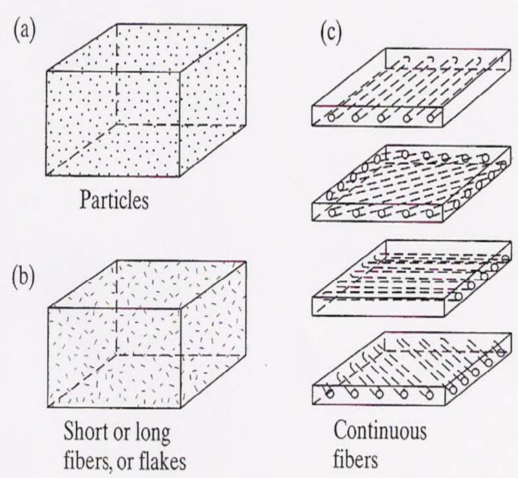

FIGURE 9.2 Schematic ilustration of methods of reinforcing plastics (matrix) with (a) particles, and (b) short or long fibers or flakes. The four layers of continuous fibers in illustration (c) are assembled into a laminate structure.

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- Designing with composite
  - A composite materials usually are more expensive on a cost.
  - Used when weight saving is possible when the relevant specific property (property/density) of the composite is better than conventional material
    - E.g. specific strength (strength/density), specific elastic modulus (elastic modulus/density)
  - Efficient use of composite can be achieved by tailoring the material for the application
    - E.g., to achieve max. strength in one direction in a fibrous composite, the fibers should be well aligned in that direction

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- If composite is subjected to tensile loading, important design criterion is the tensile strength in the loading direction
- Under compression loading, failure by buckling become important

- Fatigue behavior:
  - Steel- show an endurance limit or a stress below which fatigue does not occur
  - Composite-fatigue at low stress level because fibrous composites may have many crack, which can be growing simultaneously and propagate through the matrix

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