L-3/T-1/MME

Date: 29/09/2013

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA


Sub: MME 341 (Refractories and Furnaces)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are FOUR questions in this Section. Answer any THREE.

1. (a) List various types of crucible furnaces and describe them in brief using free hand neat sketches. (20)

(b) What are the main differences between shaft furnaces and hearth furnaces? (15)

2. (a) With the help of appropriate diagrams, write in details how waste heat recovery from the flue gas improves the furnace efficiency in terms of fuel savings. (18)

(b) Give a neat sketch and describe the working principle of a recuperative burner. (17)

3. (a) Using the following data, draw up a heat balance for a steel ingot soaking pit for a twenty hours test period during which 130 tons of ingots were heated from 20°C to 1220°C. (25)

Data:

Mean temperature of:
Air after recuperator = 620°C
Blast furnace gas (fuel) after recuperator = 450°C
Flue gas after soaking pit = 1050°C
Flue gas after air recuperator = 770°C
Flue gas after B. F. gas recuperator = 530°C
Average B. F. gas consumption = 2805 m³/hr
Air / fuel gas ratio = 0.8
Flue gas / fuel gas ratio = 1.65
Net calorific value of B. F. gas = 860 kcal/m³
Mean specific heats (kcal/m³°C) are as follows:
   Air = 0.301
   B. F. gas = 0.310
   Flue gas = 0.358
   Steel = 0.180

(All volumes are measured at 1 atm, 20°C)

Scale formation = 1.5% (by weight)
Scale formation reaction is
3Fe + 2O₂ = Fe₃O₄, ΔH₂₀°C = - 266841 kcal
Automatic weight of iron = 56
Structural loss = 270 kW

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Calculate the thermal efficiency of both the air recuperator and gas recuperator using the above data. (10)

(b) Write down the differences between a recuperator and a regenerator.

4. (a) Describe in detail the refractories that are used in different parts of blast furnace and stove. (15)

(b) Describe the working principle, indicating sequence of operation, of the furnace that is used for each of the following situations. (20)

(i) For production of liquid steel from iron scrap.
(ii) For production of liquid pig iron from iron ore.
(iii) For production of liquid steel from liquid pig iron.

SECTION - B

There are FOUR questions in this Section. Answer any THREE.

5. (a) Describe manufacturing process, properties and uses of dolomite refractories. (20)

(b) List the changes that occur during firing of siliceous materials. (15)

6. (a) Define firing shrinkage. Briefly describe the firing shrinkage curve of sedimentary kaolin. (12)

(b) How can the firing shrinkage of refractory clay be controlled by the addition of minerals? (13)

(c) What are the influences of impurities on the firing properties? (10)

7. (a) Mention and explain four general properties of a refractory material. (20)

(b) How can you select a refractory for a particular use? (15)

8. (a) Illustrate a tunnel kiln with the help of a neat sketch. How does it differ from compartment kiln? (20)

(b) List five advantages and five disadvantages of a tunnel kiln. (15)
There are EIGHT questions in this section. Answer any SIX. The figures in the margin indicate full marks.

1. Briefly discuss the structural changes that occur during crack initiation and crack growth stages of a phenomenon of fatigue failure. (17½)

2. (a) Using schematic plots, explain how fracture toughness affects design.
    (b) A 4340 steel bar is subjected to a fluctuating axial load that varies from a maximum of 330 kN tension to a minimum of 110 kN compression. Determine the bar diameter to give infinite fatigue life based on a safety factor of 2.5. (10½)
    Given, \( \sigma_u = 1090 \) MPa, \( \sigma_0 = 1010 \) MPa and \( \sigma_e = 510 \) MPa.

3. Derive the following expression for equilibrium number of vacancies, where the terms have their usual meanings. (17½)
   \[ n_v = n_0 e^{-Q_v / RT} \]

4. (a) Using examples, explain the reasons for crystals deforming at small fractions of their theoretical strengths. (10½)
    (b) Discuss the characteristics features of edge dislocations and screw dislocations. (7)

5. (a) Derive the expression for the stress required to bend a dislocation to a radius R. (12½)
    (b) Define climb and explain the mechanism for negative climb of an edge dislocation. (5)

6. (a) Explain how a Frank-Read source act as a dislocation generator. (10½)
    (b) Discuss about the possibilities of homogeneous nucleation of dislocations. (7)

7. (a) Using simple sketches discuss how edge dislocations containing jogs and kinks formed due to interactions with other dislocations can continue their movement. (12½)
    (b) Write a short note on cross slip. (5)

8. (a) The density of a specimen of HCP beryllium is 1.844 g/cm³, atomic weight 9.01 gm/mol and the lattice parameters are \( a_0 = 0.22858 \) nm and \( c_0 = 0.35842 \) nm. Calculate the fraction of the lattice points that contain vacancies. (9)
    (b) Calculate the activation energy in eV/atom for vacancy formation in aluminium, given that the equilibrium number of vacancies at 500 °C is \( 7.57 \times 10^{23} \) m⁻³. The atomic weight and density (at 500 °C) for aluminium are 26.98 g/mol and 2.62 g/cm³, respectively. (8½)

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There are EIGHT questions in this section. Answer any SIX.
The questions are of equal value.

9. The ferrite grain size of a dead soft steel is to be measured using an optical micrograph of dimension 2 inch by 2 inch. The optical micrograph was taken at 200 magnification and there were 100 grains in the specified area. Calculate the ferrite grain size of the steel sample according to ASTM Standard. Assume reasonable value for any missing data.

10. Discuss the functions of grain boundaries in a polycrystalline material. What are the possible reasons of irregularities in the stress-strain curves of some metallic alloys? With neat sketches explain the reasons.

11. Discuss how blue brittleness is induced in some metallic alloys. What are the possible effects of blue brittleness on the mechanical behaviours of these alloys?

12. What do you understand by controlled rolling process? Discuss the purposes of the controlled rolling and its underlying mechanisms responsible to modify the microstructures of the rolled materials.

13. Define solid solution strengthening. Among the alloying elements N, Mn and Ni, which one will introduce the largest solid solution strengthening effect and why?

14. Compare and contrast the creep rupture and stress rupture. Explain the method of plotting the stress-rupture data.

15. What do you understand by short-term and long-term mechanical properties? Discuss the mechanisms by which the mentioned mechanical properties are modified in super alloys.

16. What is Smith's model for microcrack formation in materials? Using the following equation, discuss how it qualitatively predicts the effects of material composition, impurity and grain size on the ductile brittle transition of material. 

\[
\frac{(\tau_D^{1/2} + K')K'}{2K} = G\gamma_S\beta
\]

All symbols in this equation have their usual meanings.
1. (a) Chemical analysis has indicated that an ore contains: 5.65% Cu; 20% Fe; 6.2% Zn; 25.9% S; 23.3% SiO₂; 10.2% Al₂O₃; 4.0% CaO; 1.0% BaO; 3.1% CO₂; 0.7% H₂O.
Mineralogical investigations have shown the presence of chalcopyrite CuFeS₂, pyrite FeS₂ and sphalerite ZnS in the ore. Determine the mineralogical composition of the ore. (15)
(b) Define ore dressing. List the importance of ore dressing. Discuss the steps involved in ore dressing. (10)
(c) Relate size of particles produced with the techniques of application of stress in the reduction of the particles. (10)

2. (a) How does a gyratory crusher differ from a jaw crusher? (10)
(b) Draw a neat sketch and explain the movement of charge in a ball mill. (20)
(c) What is meant by closed circuit grinding? (5)

3. (a) In a laboratory flotation test the following data were obtained:

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight</th>
<th>Assay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>2000g</td>
<td>2.1% Pb</td>
</tr>
<tr>
<td>Tailings</td>
<td></td>
<td>0.1% Pb</td>
</tr>
<tr>
<td>Concentrate</td>
<td>70g</td>
<td>55.1% Pb</td>
</tr>
</tbody>
</table>

Calculate the ratio of concentration, recovery and theoretical head assay. (12)
(b) What are the purposes of screening? Discuss the factors that affect the performance of screens. (12)
(c) What is classification? Explain the principle of classification. (11)

4. (a) Draw a neat sketch and explain the functioning of a dry drum magnetic separator. (15)
(b) What are frothers? (5)
(c) Explain the basic principle of floatation process. (15)
There are FOUR questions in this Section. Answer any THREE.

5. (a) The removal of the last of the sulphur in roasting is quite different; explain why. (5)
   
   (b) What is a predominance area diagram? What are its uses and limitations? (5)
   
   (c) Draw a neat sketch of a typical multiple hearth roaster and explain how roasting is performed in it. (13)
   
   (d) Explain, with a suitable phase diagram, the principles of Zone refining. (12)

6. (a) Distinguish between smelting and matte smelting. Outline, with appropriate chemical reactions, the process of extraction of copper by matte smelting. (20)
   
   (b) A copper converter receives a charge of 60 tons of matte containing 54 percent FeS which is oxidised by blowing air (21 percent oxygen) into the converter. Enough SiO\textsubscript{2} is made available to form an FeO.SiO\textsubscript{2} slag which is subsequently removed. Blowing is then continued when cuprous sulphide starts to oxidize. At a certain stage, blowing is stopped and reaction is allowed to occur between the oxide and sulphide of copper forming (blister) copper and sulphur dioxide, no excess of either constituent being left over. (15)

   (i) Calculate the volume of air necessary for oxidizing FeS.
   
   (ii) Determine the total volume of S\textsubscript{O}\textsubscript{2} produced in cubic meters.
   
   (iii) Determine the weight of slag formed.

7. (a) Draw neat sketches and explain the situations that can arise when a mineral surface dissolves in a leaching reagent. Identify the kinetic steps in each case and explain how the leaching reaction can be accelerated. (15)
   
   (b) Discuss the importance of potential/pH diagrams in leaching operations. What are its limitations? (5)
   
   (c) Explain, with appropriate chemical reactions, the purification of leach liquors by the ion exchange methods. (15)

8. (a) Consider the relative activity of metals with respect to hydrogen and explain why all metals are not amenable to electrowinning from aqueous solutions. (20)
   
   (b) What are the harmful impurities in electrical grade copper and how they are eliminated during copper electrorefining. (12)
   
   (c) List the essential properties of an electrode. (3)
SECTION - A

There are FOUR questions in this section. Answer any THREE.

1. (a) Differentiate between activation and concentration polarization and hence deduce an equation for the combined polarization of an electro-chemical cell.
   (20)

   (b) Iron is connected to magnesium and then immersed in a solution containing both Fe$^{2+}$ and Mg$^{2+}$ ions. Standard potential values are given in Table 1.
   (15)
   (i) Which metal corrodes?
   (ii) Write equations to describe the reactions which occur at each electrode.
   (iii) Calculate the maximum possible potential of the resulting corrosion cell.

2. (a) 'Gaseous oxidation may be considered as analogous to aqueous galvanic corrosion'
   — Explain the statement.
   (8)

   (b) Explain how a diffusion controlled oxidation rate can be decreased by doping in both n-type and p-type oxides.
   (15)

   (c) Define Pilling-Bedworth ratio for each of the metals listed below. Also on the basis of this value, specify whether or not you would expect the oxide scale that forms on the surface to be protective and then justify your decision. Density data for both the metal and its oxide are tabulated below.
   (12)

<table>
<thead>
<tr>
<th>Metal</th>
<th>Metal Density, gm/cc</th>
<th>Metal Oxide</th>
<th>Oxide density, gm/cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zr (Atomic wt. 90.6)</td>
<td>6.51</td>
<td>ZrO$_2$</td>
<td>5.89</td>
</tr>
<tr>
<td>Bi (atomic wt. 208)</td>
<td>9.80</td>
<td>Bi$_2$O$_3$</td>
<td>8.90</td>
</tr>
<tr>
<td>Al (Atomic wt. 27)</td>
<td>2.67</td>
<td>Al$_2$O$_3$</td>
<td>3.90</td>
</tr>
</tbody>
</table>

3. (a) With the help of an appropriate figure, explain that the anodic protection is much more efficient than the cathodic protection in acid solutions.
   (15)

   (b) Outline the principles of cathodic protection. Draw neat sketches and explain the different ways that are used to protect a structure cathodically.
   (20)

4. (a) What is mixed potential theory? Figure 1 shows different redox systems when a metal M is immersed in a ferric salt. Explain the corrosion behavior of the metal M according to the mixed potential theory.
   (20)

   (b) Write short notes on
   (i) Reference electrode
   (ii) Exchange current density
   (iii) Differential temperature cell.

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SECTION – B
There are EIGHT questions in this section. Answer any SIX.

5. (a) Shortly discuss the methods for minimising intergranular corrosion in austenitic stainless steels. (10½)
(b) What do you understand by Knife-Line attack? How can you prevent such activities in austenitic stainless steels? (7)

6. (a) Using schematic diagrams, explain the autocatalytic nature of pitting. (12½)
(b) Why pitting is considered as an intermediate stage in the aspect of corrosion. (5)

7. (a) Explain with examples the significance of cathodic to anodic area ratio in galvanic corrosion. (12½)
(b) Write down four procedures for preventing or minimising galvanic corrosion. (5)

8. 'One single mechanism for stress corrosion is not possible for all metal-environment systems.' Discuss the reason behind this statement in terms of different possible mechanisms for SCC. (17½)

9. (a) Justify the reasons for corrosion testing. (10½)
(b) How can you prepare surface for corrosion testing purposes? (7)

10. (a) Consider iron corroding in air-free acid at an electrochemical corrosion rate of 1 μA cm⁻². It dissolves as ferrous ions and the density of iron is 7.86 gm cm⁻³. Determine the penetration rate in mpy. (5½)
(b) Discuss briefly the cleaning methods after environmental exposure for the following metals/ alloys. (i) aluminium and its alloys (ii) iron and steel (iii) magnesium and its alloys (iv) stainless steels and alloys. (12)

11. Briefly discuss the effects of velocity, turbulence and impingement on erosion corrosion. Draw schematic diagrams if necessary. (17½)

12. What do you understand by fretting corrosion? What are the basic requirements of fretting corrosion? Using schematic diagrams explain the wear-oxidation and oxidation-wear concepts of fretting corrosion. (17½)
### Table 1: The Standard emf Series

<table>
<thead>
<tr>
<th>Electrode Reaction</th>
<th>Standard Electrode Potential, $E^\circ$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au$^{3+}$ + 3e$^-$ $\rightarrow$ Au</td>
<td>+1.420</td>
</tr>
<tr>
<td>O$_2$ + 4H$^+$ + 4e$^-$ $\rightarrow$ 2H$_2$O</td>
<td>+1.229</td>
</tr>
<tr>
<td>Pt$^{4+}$ + 2e$^-$ $\rightarrow$ Pt</td>
<td>+1.2</td>
</tr>
<tr>
<td>Ag$^{+}$ + e$^-$ $\rightarrow$ Ag</td>
<td>+0.800</td>
</tr>
<tr>
<td>Fe$^{3+}$ $+$ e$^-$ $\rightarrow$ Fe$^{2+}$</td>
<td>+0.771</td>
</tr>
<tr>
<td>Increasingly inert (cathodic)</td>
<td></td>
</tr>
<tr>
<td>O$_2$ $+$ 2H$_2$O $+$ 4e$^-$ $\rightarrow$ 4(OH)$^-$</td>
<td>+0.401</td>
</tr>
<tr>
<td>Cu$^{2+}$ $+$ 2e$^-$ $\rightarrow$ Cu</td>
<td>+0.340</td>
</tr>
<tr>
<td>2H$^+$ $+$ 2e$^-$ $\rightarrow$ H$_2$</td>
<td>0.000</td>
</tr>
<tr>
<td>Pt$^{2+}$ $+$ 2e$^-$ $\rightarrow$ Pt</td>
<td>-0.126</td>
</tr>
<tr>
<td>Sn$^{2+}$ $+$ 2e$^-$ $\rightarrow$ Sn</td>
<td>-0.136</td>
</tr>
<tr>
<td>Ni$^{2+}$ $+$ 2e$^-$ $\rightarrow$ Ni</td>
<td>-0.250</td>
</tr>
<tr>
<td>Co$^{2+}$ $+$ 2e$^-$ $\rightarrow$ Co</td>
<td>-0.277</td>
</tr>
<tr>
<td>Cd$^{2+}$ $+$ 2e$^-$ $\rightarrow$ Cd</td>
<td>-0.403</td>
</tr>
<tr>
<td>Fe$^{3+}$ $+$ 2e$^-$ $\rightarrow$ Fe</td>
<td>-0.440</td>
</tr>
<tr>
<td>Increasingly active (anodic)</td>
<td></td>
</tr>
<tr>
<td>Cr$^{3+}$ $+$ 3e$^-$ $\rightarrow$ Cr</td>
<td>-0.744</td>
</tr>
<tr>
<td>Zn$^{2+}$ $+$ 2e$^-$ $\rightarrow$ Zn</td>
<td>-0.763</td>
</tr>
<tr>
<td>Al$^{3+}$ $+$ 3e$^-$ $\rightarrow$ Al</td>
<td>-1.662</td>
</tr>
<tr>
<td>Mg$^{2+}$ $+$ 2e$^-$ $\rightarrow$ Mg</td>
<td>-2.363</td>
</tr>
<tr>
<td>Na$^{+}$ $+$ e$^-$ $\rightarrow$ Na</td>
<td>-2.714</td>
</tr>
<tr>
<td>K$^+$ $+$ e$^-$ $\rightarrow$ K</td>
<td>-2.924</td>
</tr>
</tbody>
</table>

Table 1 for question 1(b)

![Figure 1 for question 4(a)](image-url)