GWANDA STATE UNIVERSITY

FACULTY OF ENGINEERING AND THE ENVIRONMENT

DEPARTMENT OF METALLURGICAL ENGINEERING

CORROSION AND WEAR

EMR 5203

Part V Second Semester Examination Paper

AUGUST 2022

This examination paper consists of 4 printed pages

Time Allowed: **3 hours**

Total Marks: **100**

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INSTRUCTIONS

1. Answer any 4 questions
2. Each question carries 25 marks
3. Use of calculators is permissible.

1. Materials in use fails due to corrosion and/or wear, be it in industry or in society. Consider a farm tractor
   a. In what way can corrosion affect the tractor's life of use? [2]
   b. How can this corrosion failure mentioned above in (a) be circumvented at design level of the tractor? [4]
   c. How can this corrosion failure mentioned above in (a) be delayed at operational level of the tractor? [4]
   d. In what way can frictional wear affect the tractor's life of use [2]
   e. How can this frictional wear failure mentioned above in (d) be circumvented at design level of the tractor? [4]
   f. How can this frictional wear failure mentioned above in (d) be delayed at operational level of the tractor? [4]
   g. In what two ways can material corrosion accelerate abrasive wear? [5]

2. In operation of a ball mill the best milling efficiency is obtained when the mill balls are of near equal diameter. A small scale mine two tonnes per hour capacity ball mill uses 40mm diameter forged steel balls with a wear rate time constant of 1.35 E-03 hr^{-1}. The mill balls cost $800 per tonne.

$$T = \frac{6.9}{k} \log_{10}\left(\frac{D_a}{D_b}\right)$$

$$R = kW$$

where T – Time in hours for change in diameter from D_a to D_b in mm
k – wear time constant in hr^{-1}
R- rate of wear of a ball of weight W kg

   a. What size of balls will need to be added after one full day of operation to maintain equal ball diameter? [6]
   b. How many of these balls are to be added if the ball loading is to be maintained to the initial loading? [3]
   c. What is the ball cost per tonne of ore milled? [3]
   d. Different mill balls, high chromium cast iron, are proposed to be used. Their wear rate time constant is 8.4E-03hr^{-1} and cost of $1000/ton. What is will be the saving or loss per day in cost of mill balls used if changed to high chromium cast iron? [9]
   e. What two factors can accelerate mill ball wear in ball mills? [4]

3. A mine is developing a new hydrometallurgical leaching method using sodium hypochlorite (NaOCl) as a lixiviant instead of Sodium Cyanide (NaCN). During laboratory test work the pulp pH in leach cells start at 11 and ends at 4 in each batch leach cycle. As a Materials Engineer you have decided to use 304-stainless steel for the leaching vessels.
    a. Explain the mechanism of corrosion resistance in stainless steel and how it is different from steels? [5]
    b. Under what conditions will stainless steel corrode and why? [4]
    c. List three common types of stainless steel corrosion [6]
    d. Will 304-stainless steel suffice for the task and what are pros or cons in using it as a NaOCl leach tank vessel material? [4]
    e. What three recommendations would you advice fabricators and operators of this plant that will result in prolonged life of these vessels [6]

4. Cadmium is in hydrochloric acid at a pH of 1. The concentration of Cd^{2+} in solution is 10^{-5}M
   Given:
   E^o=-0.360V vs SHE for $Cd^{2+}|Cd$
   b_a=0.100V / decade
   b_c=-0.120V / decade
   a_c=1.4V/decade
   $i^o_{Cd}=10^{-6}$A/cm^2
   $i^o_{H2}=10^{-8}$A/cm^2

   Calculate the
    a. Corrosion potential, [8]
    b. Corrosion current, [8]
    c. Protection current, needed to stop corrosion of Cadmium in a corrosive de-aerated medium [5]
    d. In what other two ways can the rate of corrosion for cadmium be reduced [4]

5. PetroZim Private Limited uses cathodic protection to guard against corrosion of the Feruka Msasa fuel pipeline. Information in the table below was extracted from the cathodic protection of the steel pipeline.

Parameter	Drain Point 1	Drain Point 2
Drainage current measured, I_{om} (A)	16.6	9.8
Potential increase measured at the end of the section, ΔE_L (V)	0.26	0.26
Attenuation coefficient, α (km^{-1})	0.5	0.5
Protected Pipe Length, L (km)	3.86	3.86
Measured potential increase at the drainage point, ΔE_{om} (V)	0.83	0.83
Drainage Current Coefficient, k_i	1.5	1.5
Resistance of lead wire, ρ_w ($\Omega mm^2 m^{-1}$)	0.0015	0.0015
Resistance of backfill ρ_a ($\Omega mm^2 m^{-1}$)	0.0052	0.0052
Resistance of soil ρ_s ($\Omega mm^2 m^{-1}$)	0.096	0.096
Length of lead wire l_w (m)	375	375
Length of the anode l_a (m)	1.1	1.1
Length of the anode with coke breeze backfill, l (m)	4.82	4.82
Depth of the anode ground-bed, t (m)	2	2
Wire cross section, a (mm^2)	15.5	15.5
Radius of the backfill, d_{bf} (m)	1.25	1.25
Radius of the anode, d_a (m)	0.28	0.28
Weight of a single anode of Fe-Si, W_a (kg)	68	68
Anode wear rate, R (kg/A year)	0.07	0.07
Accepted current per anode, I_a (A)	5.0	5.0

a. Calculate potential at the drainage point [5]
b. Compare the calculated to the measured potential value [2]
c. Calculate the resistance of the pipe [5]
d. Calculate the current at the drainage point [5]
e. Calculate the anode resistance [5]
f. Calculate the number of anodes in the ground bed [3]

END OF QUESTION PAPER