CPN321 Modelling Project

Part 2

September 2017

# System Description

Gold can be leached from ore using cyanide to form aurocyanide followed by adsorption onto activated carbon. A “Carbon in leach” (CIL) reactor facilitates both the leaching and adsorption steps in a single vessel. An ore slurry is continuously fed to the CIL vessel while a second line is used to dose the ore with cyanide. The flowrate of the ore slurry is subject to upstream process conditions while the rate of cyanide dosing can be controlled. The vessel is sparged with air at atmospheric pressure and mass transfer is sufficiently rapid to ensure that the dissolved oxygen is always at the saturation concentration. The gold leaching reaction is given be Equation 1, and the rate at which gold is leached is given by Equation 2:

(1)

(2)

Where *kl* is the reaction rate constant, [·] indicates the molar concentration of a chemical species and [Au(CN)2−]∗ is the aurocyanide equilibrium concentration.

Activated carbon is fed to the CIL in a semi-batch fashion: every 5 minutes, the activated carbon is removed from the CIL by filtration and replaced. The removal and replacement takes 30 seconds. The rate *ra* of the adsorption reaction (see Equation 3) is described by the Freundlich isotherm (Equation 4):

(3)

(4)

Where *ra* is the adsorption rate constant, *α* and *β* are Freundlich isotherm constants, and [Au(CN)2–]carbon is the molar amount of aurocyanide adsorbed per gram activated carbon.

Typically, CIL tanks are arranged into trains. Consider two connected CIL reactors, as shown in Figure 1

The cyanide concentrations in the dosing lines [CN−]*D* are constant. Each CIL tank has a slurry volume *Vi* (m3) and an activated carbon loading *ρC,i* (kg*/*m3). Tank 1 receives the feed slurry. The slurry from tank 1 flows to tank 2, while the activated carbon from tank 2 is moved to tank 1 and replaced by fresh carbon every five minutes as described above. The CIL reactors are operated to ensure the slurry volume as well as the mass of

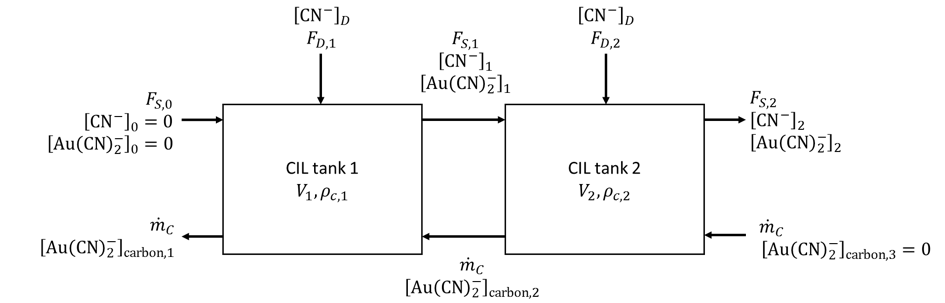


Figure 1: CIL Reactors in series

activated carbon in each reactor remains constant throughout the process. This implies that *FS,*1 = *FS,*0+*FD,*1 and *FS,*2 = *FS,*1+*FD,*2, where *FS* and *FD* are the liquid volumetric flowrate of the slurry and dosing streams respectively. The mass flowrate of activated carbon is equal in each stream. For the purposes of this assignment, you may assume that the batch process described above can be approximated by a constant carbon flow rate. The activated carbon from tank 2 is removed for downstream gold elution.

# 2 Model

The system equations are shown in Table 1. A description of parameter, input and output names as well as initial steady state values are presented in Table 2, 3 and 4.

Table 1: System equations

|  |  |  |  |
| --- | --- | --- | --- |
| Equations | Parameters | Inputs | Outputs |
| *Cyanide component balance*  1  2 | ,  V1= V2 | FD,1, FD,2 |  |
| *Aurocyanide component balance* 3  4 |  |  |  |
| 5  6 |  |  |  |
| *CIL reactor volumetric balance*  7  8 |  |  |  |
| *Oxygen concentration*  9  10 |  |  |  |
| *Reaction equations*  11  12 |  |  |  |
|  |  |  |  |
| 13  14 |  |  |  |
| Total: 29 = | 9 | +6 | +14 |

|  |  |  |
| --- | --- | --- |
| Parameters | Parameter value | Description |
|  | 2.6 ×10-5 `kmol.m-3 | Aurocyanide equilibrium concentration |
|  | 9.5 kmol.m-3 | Cyanide concentration in dosing line |
|  | 2.5 m3 | Volume of CIL tank |
|  | 16 kg.m-3 | Density of activated carbon loading in tank |
|  | 1300 kmol.m-3.atm-1 | Henry’s law constant |
|  | 1.215 m3.kmol-1.s-1 | Reaction rate constant |
|  | 45 m3.kmol-1.s-1 | Adsorption rate constant |
|  | 4500 | Freudlich isotherm constants |
|  | 0.9 | Freudlich isotherm constants |

Table 2: Parameters

Table 3: Inputs

|  |  |  |
| --- | --- | --- |
| Inputs | Steady state values | Description |
|  | 2.86 × 10-4  m3.s-1 | Dosing line flow in |
|  | 0.328 m3.s-1 | Feed slurry flow in |
|  | 1.33 kg.s-1 | Activated carbon loading |
|  | 0.21 atm | Pressure of oxygen in tank |

Table 4: Outputs

|  |  |
| --- | --- |
| Outputs | Description |
|  | Cyanide concentration in tank |
|  | Aurocyanide concentration |
|  | Molar amount of absorbed aurocyanide per gram activated carbon |
|  | Slurry flow rate in tank |
|  | Oxygen concentration in tank |
|  | Rate of reaction in tank |
|  | Rate of adsorption in tank |

# 3 Instructions

You will be required to simulate the given system for a series of dynamic events. You have been provided with a notebook as a starting point for your work. You will simulate 1000s of plant operating time, starting at a nominal steady state which you will calculate from the information provided.

**1. Steady state (30 marks)**

Calculate the initial values of all the variables in the system given the steady state input values and parameters. You should write a single function that when called produces a list of all the outputs as specified in the given notebook. Note that CN\_1 in the notebook refers to [CN- ] in tank 1 etc. (The notation is self-explanatory).

**2. Dynamic simulation (basic) (60 marks)**

Simulate the system using only the equations given and scipy.integrate.odeint as your tool for numeric integration. Your program should calculate initial conditions using your function from Question: 1.

Show the effect of the following input step changes (all in one simulation run):

* 1) a 10% step increase in F\_D1 at t = 100s
* 2) a 10% step increase in F\_s0 at t = 250s
* 3) a 10% step decrease in p\_O22 at t = 600s

Plot the combined dynamic effect of these changes on each of the 6 state variables (6 plots).

**3. Simulation with dead time (45 marks)**

Consider now a situation where a long pipe is used to transport liquid material between the two tanks. The flow in the pipe conforms to a plug flow model and no reaction occurs in the pipe, so that effectively a delay is introduced in the concentrations, and entering the 2nd tank. The deadtime incurred is 100 s.

Using the same set of input steps, show the effect of the dead time by plotting the following curves:

1)

(leaving the 1st tank) and (concentration of cyanide from 1st tank in the stream entering the 2nd tank at time t ) – on the same graph.

2)

(t) for the system with dead time and (t) without dead time on the same graph. This refers to the concentration of aurocyanide in the 2nd tank at time t.

Comment on the effect dead time has on this system. Note that, since you are using Euler integration here and your values are small, step size is very important. If step size is too large you might find yourself calculating a negative value for a state which will break your simulation.

**4. Valve simulation** (**45 marks)**

Modify your simulation (without dead time) to include the effect of an equal percentage pneumatic control valve on the inlet, .

The Pressure signal to the valve can vary from 20 to 100 kPa. The valve dynamics are well described below. Size your valve so that it is open halfway (x = 0.5) at initial conditions where the pressure signal to the valve is 60 kPa, and so that if your valve is closed to 25% (x = 0.25), the flow, F\_D1, will decrease by 25%. You may assume a constant pressure drop of 1 atm over the valve.

Consider the following step changes:

1. An increase in valve pressure signal (Ps) from 60 kpa to 70 kpa at t = 200s.
2. A decrease in valve pressure signal from 70 kpa to 50 kPa at t = 500s.

Plot the following:

1. Ps(t) (valve pressure signal) and valve fraction (x(t)) as 2 subplots (one under the other)
2. on a separate plot. (The concentration of aurocyanide adsorbed to carbon in the 2nd tank)

# Equations describing valve dynamics:

|  |  |  |
| --- | --- | --- |
|  |  | () |

Where and are valve constants (functions of geometry and size), while is given and is valve fraction.

|  |  |  |
| --- | --- | --- |
|  |  | () |

Where Ps is valve pressure signal, Kf is a constant, and and are the time constant and damping coefficient with values given below.

**5. Bonus question** (**5 marks)**

Comment on the performance of the control valve with respect to its dynamic behaviour. What effect could this behaviour have on the performance and longevity of the plant equipment in terms of stability, safety etc. and how might this affect the performance of the control system used to reject disturbances and maintain set points.

**Total: 180 Marks**