# CHL202 : PROCESS DYNAMICS & CONTROL
## MAJOR EXAMINATION: 3rd May 2008, 10:30 am -12:30 pm in WS-209

(TOTAL MARKS = 50)

1. In a fed-batch reactor, glucose concentration is measured by a sensor and controlled by a simple PI controller. The transfer function for the process is given by $G_p = \frac{8}{2s+1}$, the sensor transfer function is given by $G_m = \frac{3e^{-3s}}{s+1}$ and the PI controller transfer function given by $G_C = K_C\left(1+\frac{1}{15s}\right)$. If a bode criterion of phase margin 45° is required for satisfactory operation of the fed-batch reactor, determine the maximum allowable value for $K_C$ for stable operation. It may be assumed that all other loop elements have transfer functions = 1.

(10 marks)

2. In a fed-batch process for producing threonine the substrate uptake rate (after linearization) is given by the following equation

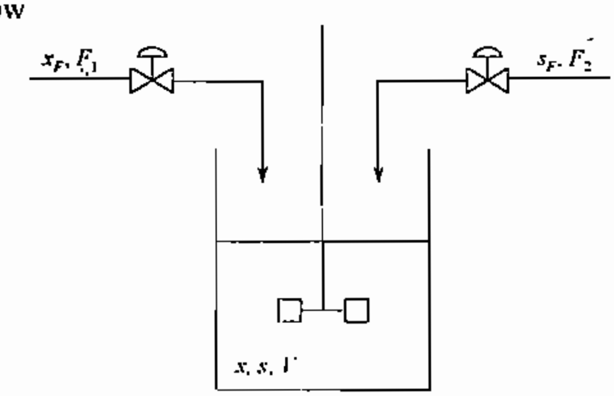
$\frac{d\tilde{s}}{dt} = -0.565\tilde{s} - 0.334\tilde{x} + 21.5\tilde{D}$, where $\tilde{s}, \tilde{x}, \tilde{D}$ are the deviation variables for the substrate and cell concentrations, and the dilution rate respectively, about the nominal steady states $s_0$=3.5, $x_0$=12=$x^*$ and $D_0$=0. The synthesis of threonine is given by the equation

$\frac{dp}{dt} = \alpha\frac{\mu_M x}{K_M + s} + \beta x - Dp$, where $\alpha = 0.1, \beta = 0.05, \mu_M = 0.46, K_M = 10$ are the parameters in appropriate units; $p$ is the product concentration. The production of threonine occurs after the cell concentration reaches $x^*$ and remains constant at that value for the remainder of the process. Unfortunately, threonine cannot be measured on-line.
It is desired to control threonine along a linear path $p(t) = 0.005 + 0.0167t$

a) Develop a control strategy for this process. What kind of controller is this?
b) Draw the block diagram and discuss

(6+4 marks)

3. A fed-batch fermentation process has two inlet streams, one feeding substrate and the other feeding cell mass (containing only the desired type of microorganism), as shown in the figure below




The cell growth follow the Monod kinetics $\frac{\mu_M s}{K_M + s}x$ and there is a significant requirement of substrate for maintenance (maintenance coefficient is $m_S$). The parameters required for describing the process are

$\mu_M = 0.3, K_M = 5, Y_{X/S} = 0.5, s_F = 50, x_F = 20$ and $m_S = 0.01$. Assume that the process is initially at steady state and has the conditions $x_0 = 10, s_0 = 3$ and $F_{1,0} = F_{2,0} = 0$

a) Develop the linearized model for this process.

b) Derive the relative gain array for this system and comment on the degree of interaction.

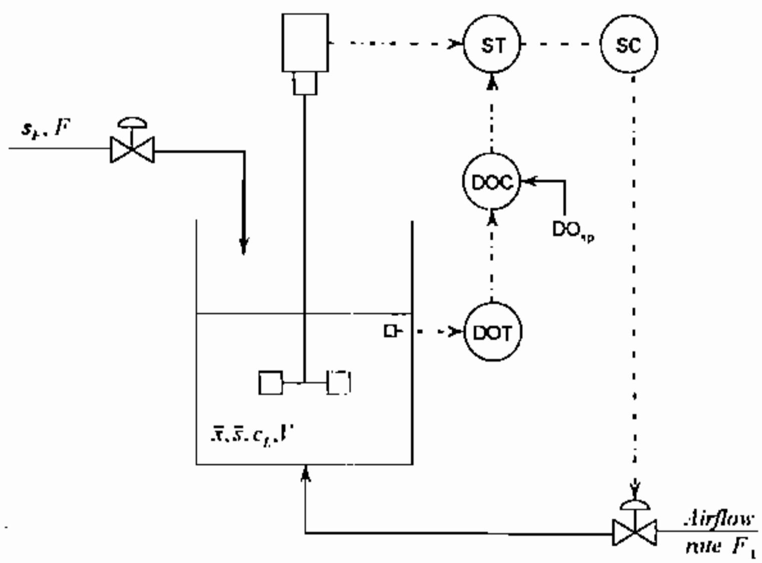
c) Determine the type of configuration (1-1/2-2 OR 1-2/2-1) suitable for this process. If proportional controllers are used for this process, $K_{c1} = 10$ and $K_{c2} = 15$, draw the configuration and write the characteristic equation for this process.

(5+5+5 marks)

4. The schematic diagram for cascade control of dissolved oxygen concentration $c_L$ is shown in the figure below. The process equations are given by

$$\frac{dc_L}{dt} = -\frac{\mu_M \bar{s}\bar{x}}{(K_{M1} + \bar{s})(K_{M2} + c_L)} + 0.026N^{1/2}(c_L^* - c_L)$$

$$\frac{dN}{dt} = -40F_A - 10N$$




Where $c_L$ is the dissolved oxygen concentration, $c^*_L$ is the saturated dissolved oxygen concentration, $N$ is the speed of rotation of the impeller. $F_A$ is the airflow rate. $\bar{x}, \bar{s}$ are the quasi-steady-state values of the cell and substrate concentrations (held constant by the feed flow rate). The parameters for this process are given by

$\mu_M = 0.5, \bar{s} = 4, \bar{x} = 10, K_{M1} = 6, K_{M2} = 0.004, c_L^* = 0.008$ and the initial conditions are given $F_{A0} = 0, N_0 = 300, c_{L0} = 0.004$. The controllers are represented by DOC and SC in the diagram and are both PI controllers. DOC has the transfer function $G_{c1} = 50(1 + \frac{1}{10s})$ while SC has the transfer function $G_{c2} = K_{c2}(1 + \frac{1}{s})$. The transmitters DOT and ST have the gains $G_{M1} = 1$ and $G_{M2} = 10$, respectively. The valve transfer function is $G_V = 5$. The subscript "1" is for the master loop, and "2" is for the slave loop.

a) Develop the cascade control block diagram with the corresponding transfer functions.

b) Determine the transfer function $C_L(s)/C_{L,sp}(s)$ and the Characteristic Equation for this process

c) What is the restriction on $K_{c2}$ for closed-loop stability

(5+5+5 marks)