Ransford Antwi

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EGR102

Final Project Practice Part 2: Simulate Bioreactor for Protein Production with Step Response

Due: Sunday at Midnight March 31st, 2024

The assignment is to simulate a BIOREACTOR WITH SUBSTRATE INHIBITION.

You will be building off this system to

1. Simulate the continuous bioreactor for a time frame with fixed inputs.
2. Simulate the continuous bioreactor with a step response in flow rate.
3. Fit baseline maximum growth rate, µmax (mu\_max), given set of data.
4. Fit growth kinetics for max growth rate µmax, the Monod Constant, K, and inhibition factor Ki.

EC) Optimize Fin for best production.

Modeling Equations:

Note: growth rate µ(mu) should be in the ODE function file.

% Simulation Parameters

t\_end=40; % total simulation hrs

delt=0.1;% sample time hrs

t\_step=5;% step time in hrs

% Initial Conditions:

X(1)= 49.9097;% g cells/ L

S(1)= 5.1327;% g substrate/ L

P(1)= 24.9548;% g protein /L

%Nominal Parameter Values (To Be Fitted):

mu\_max = 0.5;% maximum growth rate h-1

K= 20;% Monod growth constant g substrate/L

Ki= 50;% Substrate inhibition growth constant g substrate/L

% Input

Fin\_init=100;% initial feed flow rate L/hr

Fin\_final=150;% final feed flow rate L/hr

% Parameters:

V=1000;% bioreactor volume L

YSX = 1.5;% yield g substrate/ g cells

YPX = 0.5;% yield g protein/ g cells

Xin = 0;% feed biomass concentration g cells/L

Sin = 80;% feed substrate concentration g substrate/L

Pin = 0;% feed protein concentration g protein/L

1. Generate one figure with 4 subplots:
   1. Title should be: Final Project Part 2 with mu max= “mu\_max”, K=”K” , and Ki=”Ki” NOTE:”” are embedded parameters
   2. t vs X with yaxis “X (g cells/L)”
   3. t vs S with yaxis “S (g substrate/L)”
   4. t vs P with yaxis “P (g protein/L)”
   5. t vs Fin with yaxis “Fin (L/hr)” and xaxis “Time (hrs)”

Paste here the following:

1. final\_project\_part2\_ic.m file
2. final\_project\_ode.m file
3. figure generated

Save all files since will be building on these for subsequent parts!

*If done right will get a figure like this:*

A graph on a white background

Description automatically generated

i). Final\_project\_part2\_ic.m file

%Bioreactor\_Step\_ic%

%Ransford Antwi%

%March 5, 2024%

%Final Project Part 2

%blank slate%

clear

clc

% user assigned%

% Simulation Parameters

t\_end=40; % total simulation hrs

delt=0.1 ;

t\_step=5;

% Initial Conditions:

X(1)= 49.9097;% g cells/ L

S(1)= 5.1327;% g substrate/ L

P(1)= 24.9548;% g protein /L

%Nominal Parameter Values (To Be Fitted):

mu\_max = 0.5;% maximum growth rate h-1

K= 20;% Monod growth constant g substrate/L

Ki= 50;% Substrate inhibition growth constant g substrate/L

%Input

%Fin=100;% feed flow rate L/hr

Fin\_init=100;% initial feed flow rate L/hr

Fin\_final=150;% final feed flow rate L/hr

%Parameters

V=1000;% bioreactor volume L

Ysx = 1.5;% yield g substrate/ g cells

Ypx = 0.5;% yield g protein/ g cells

Xin = 0;% feed biomass concentration g cells/L

Sin = 80;% feed substrate concentration g substrate/L

Pin = 0;% feed protein concentration g protein/L

%main program

%[xdot]=lorenz\_ode\_2(t,x,opts,sigma,r,b)

%intialization

x0=[X(1);S(1);P(1);];

%unpacking to various parameters

param(1)=V;

param(2)=Ysx;

param(3)=Ypx;

param(4)=Xin;

param(5)=Sin;

param(6)=Pin;

param(7)=mu\_max;

param(8)=K;

param(9)=Ki;

%initial time

t(1)=0;

Fin(1)=Fin\_init;

%number of samples

N=ceil(t\_end/delt);

for i=2:N

t(i)=t(i-1)+delt;

if t(i)>=t\_step

Fin(i)=Fin\_final;

else

Fin(i)=Fin\_init;

end

%[xdot]=vdv\_fxn(t,x,opts,param,u)

[~,Xout]=ode45('Bioreactor\_fxn',[t(i-1) ,t(i)],x0,[],param,Fin(i-1));

%unpack Xout to common notation for states

X(i)=Xout(end,1); %all data points for colunm 1

S(i)=Xout(end,2);

P(i)=Xout(end,3);

x0=[X(i);S(i);P(i)];

end

%Graphing

%ploting subplot

figure(1);

subplot(4,1,1);plot(t,X) %ploting

ylabel('X(g cells/L')

title(['Final Project Part 1 with mumax=',num2str(mu\_max),'K=',num2str(K),'and Ki=',num2str(Ki)])

subplot(4,1,2);plot(t,S)

ylabel('S(g substrate/L')

subplot(4,1,3);plot(t,P)

ylabel('P(g Protein/L')

subplot(4,1,4);plot(t,Fin)

xlabel('Time(hrs)')

ylabel('Fin(g L/hr)')

ii). Final\_project\_ode.m file

%Bioreactor\_fxn\_ode

%Ransford Antwi

%user assigned

% Simulation Parameters

% t\_end=100; % total simulation hrs

%

% % Initial Conditions:

% X(1)= 0.1;% g cells/ L

% S(1)= 20;% g substrate/ L

% P(1)= 0;% g protein /L

%

% %Nominal Parameter Values (To Be Fitted):

% mu\_max = 0.5;% maximum growth rate h-1

% K= 20;% Monod growth constant g substrate/L

% Ki= 50;% Substrate inhibition growth constant g substrate/L

% Input

%Fin=100;% feed flow rate L/hr

% Parameters

% V=1000;% bioreactor volume L

% YSX = 1.5;% yield g substrate/ g cells

% YPX = 0.5;% yield g protein/ g cells

% Xin = 0;% feed biomass concentration g cells/L

% Sin = 80;% feed substrate concentration g substrate/L

% Pin = 0;% feed protein concentration g protein/L

%main program

function [xdot]=bioreactor\_ode(t,x,opts,param,Fin)

X=x(1); %position must match

S=x(2);

P=x(3);

%packing elements to param

V=param(1);

Ysx=param(2);

Ypx=param(3);

Xin=param(4);

Sin=param(5);

Pin=param(6);

mu\_max=param(7);

K=param(8);

Ki=param(9);

%ODE

mu=mu\_max\*S/(K+S+(S^2/Ki));

dXdt=(Fin\*(Xin-X))/V+mu\*X;

dSdt=(Fin\*(Sin-S))/V-Ysx\*mu\*X;

dPdt=(Fin\*(Pin-P))/V+Ypx\*mu\*X;

xdot=[dXdt;dSdt;dPdt];

iii). Figure generated

