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COLLEGE OF ENGINEERING

DEPARTMENT OF CHEMICAL AND PETROLEUM ENGINEERING
CHEMICAL ENGINEERING PROGRAMME

Process Dynamics and Control II (CHE 532) Assignment I

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MATRIC NO: 13/ENG01/009

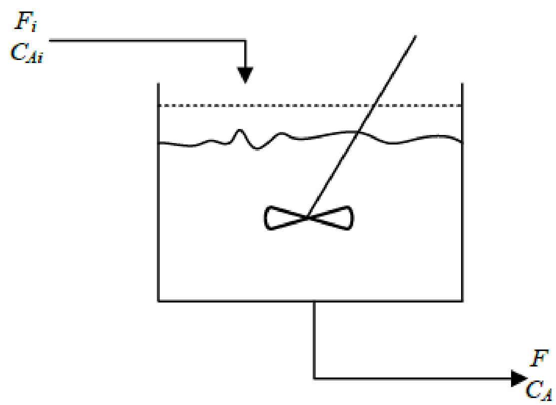

Figure 1: A constant volume isothermal continuous stirred tank reactor

Solution (Question 1a)

Doing a mass balance, we know that

$$Accumulation = in - out + gen$$

$$Mw\frac{dn}{dt} = \quad Mw(F_iC_{Ai} - FC_A - rV)$$

$$r = kC_A$$

$$V\frac{dC_A}{dt} = \quad F_iC_{Ai} - FC_A - kC_AV$$

$$Since\ Volume = Constant, \qquad therefore\ F = F_i$$

We have that

$$V\frac{dC_A}{dt} = \quad F(C_{Ai} - C_A) - kC_A V \quad \text{(Dynamic State Model)}$$

$$V\frac{dC_{As}}{dt} = \quad F(C_{Ais} - C_{As}) - kC_{As} V \quad \text{(Steady State Model)}$$

Therefore, the deviation variable model (derived from the steady state model subtracted from the dynamic state model) is shown below

$$V\frac{d}{dt}(C_A - C_{As}) = \quad F(C_{Ai} - C_{Ais}) - F(C_A - C_{As}) - k(C_A - C_{As})V$$

Let $C_{Ai} - C_{Ais} = \bar{C}_{Ai}$

$$C_A - C_{As} = \bar{C}_A$$

$$V\frac{d\bar{C}_A}{dt} = \quad F(\bar{C}_{Ai} - \bar{C}_A) - kV\bar{C}_A$$

Taking Laplace of both sides, we have

$$V[s\bar{C}_{A(s)} - \cancel{\bar{C}_{A(0)}}] = F(\bar{C}_{Ai(s)} - \bar{C}_{A(s)}) - kV\bar{C}_{A(s)}$$

$$Vs\bar{C}_{A(s)} = F(\bar{C}_{Ai(s)} - \bar{C}_{A(s)}) - kV\bar{C}_{A(s)}$$

$$Vs\bar{C}_{A(s)} + F\bar{C}_{A(s)} + kV\bar{C}_{A(s)} = F\bar{C}_{Ai(s)}$$

$$\bar{C}_{A(s)}[Vs + F + kV] = F\bar{C}_{Ai(s)}$$

The transfer function model is therefore analyzed below as;

$$G_{(s)} = \frac{output}{input} = \frac{\bar{C}_{A(s)}}{\bar{C}_{Ai(s)}} = \frac{F}{Vs + F + kV} = \frac{F}{Vs + (F + kV)}$$

Solution (1bi)

Given that $V = 2.1m^3, k = 0.04\min^{-1}, F = 0.085\dfrac{m^3}{\min}$

We have that

$$G_{(s)} = \frac{0.085}{2.1s + (0.085 + 0.04 \times 2.1)} = \frac{0.085}{2.1s + 0.169}$$

The MATLAB codes, Simulink model and graph for the open loop dynamic response are shown below;

processmodel.m

```
commandwindow
clear all
clc
bdclose all

F=0.085; % m^3/min
V=2.1; % m^3
k=0.04; % min^-1

steptime=0.5
ufinal=1.5
open('processmodelsim')
[t,x,y]=sim('processmodelsim', [0 100])
plot(t,y)
xlabel('Time(mins)')
ylabel('Concentration(mol/m^3)')

```

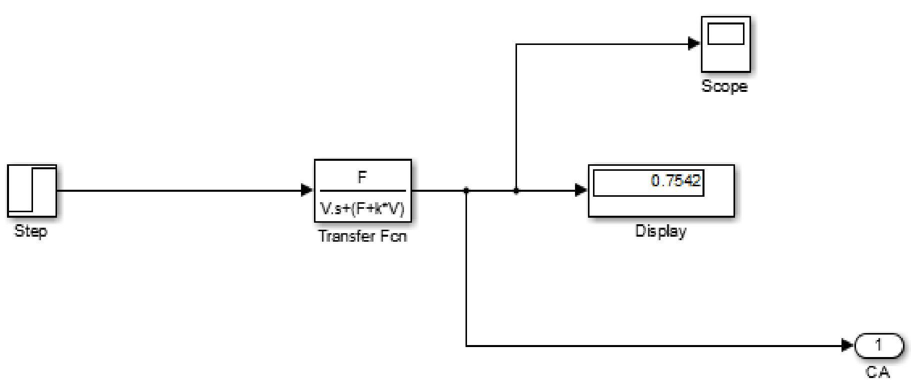

Figure 1.0: Simulink model for open loop dynamic response

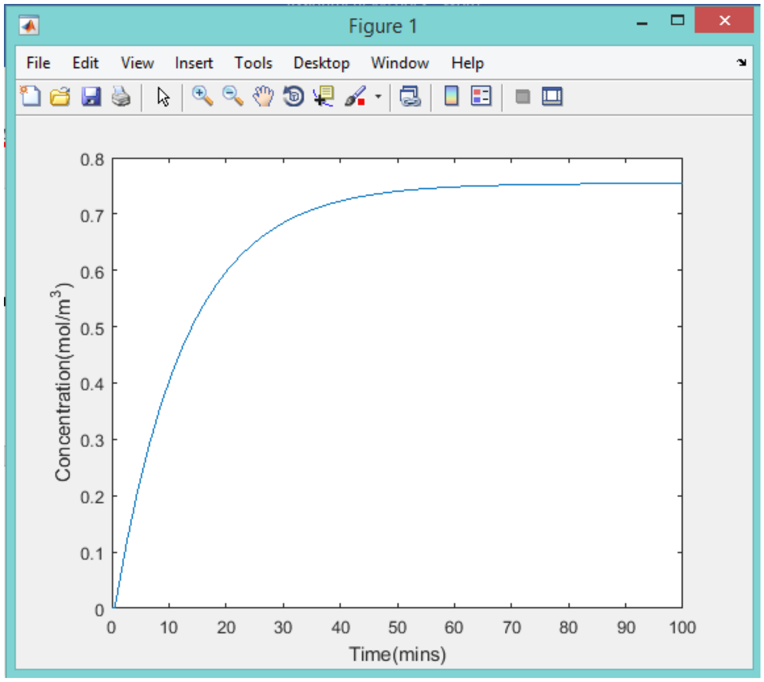

Figure 1.1: Graphical plot obtained for open loop dynamic response

Solution (Question 1bii)

The MATLAB codes, Simulink model and graph for the closed loop dynamic response are shown below;

processmodel.m processmodeldynsim.m +

```
commandwindow
clear all
clc
bdclose all

F=0.085; % m^3/min
V=2.1; % m^3
k=0.04; % min^-1
steptime=0.15;
ufinal=2.5;

Kc=0.5;
P=Kc
tauI=0.3;
tauD=0.1;
I=Kc/tauI
D=Kc*tauD

open('processmodeldyn')
[t,x,y]=sim('processmodeldyn', [0 150])
plot(t,y)
hold on
ssvalue=ufinal*1
osas=length(y)
ssvalueg=ssvalue*ones(osas,1)
plot(t, ssvalueg)
xlabel('Time(mins)')
ylabel('Concentration(mol/m^3)')
legend('Dynamic response', 'Set point')
```

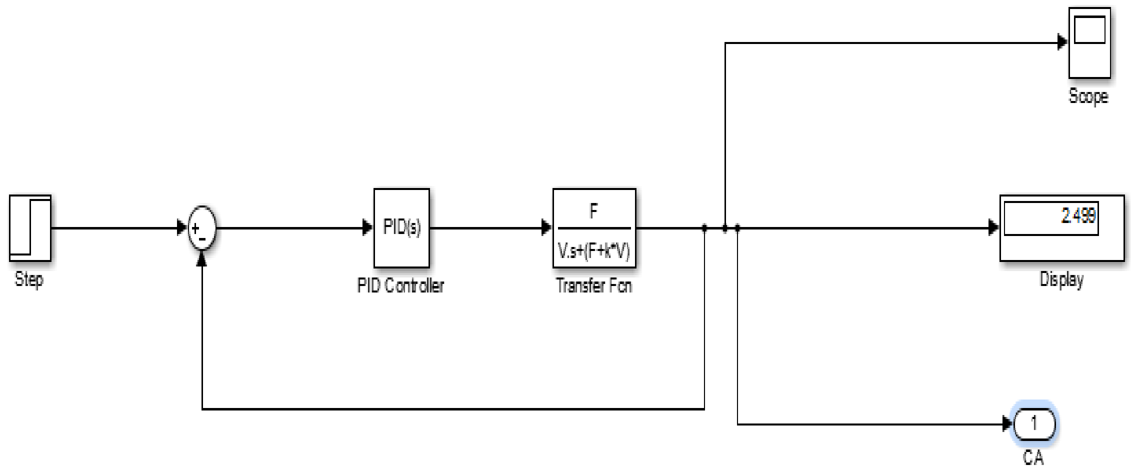

Figure 1.2: Simulink model for closed loop response for the system

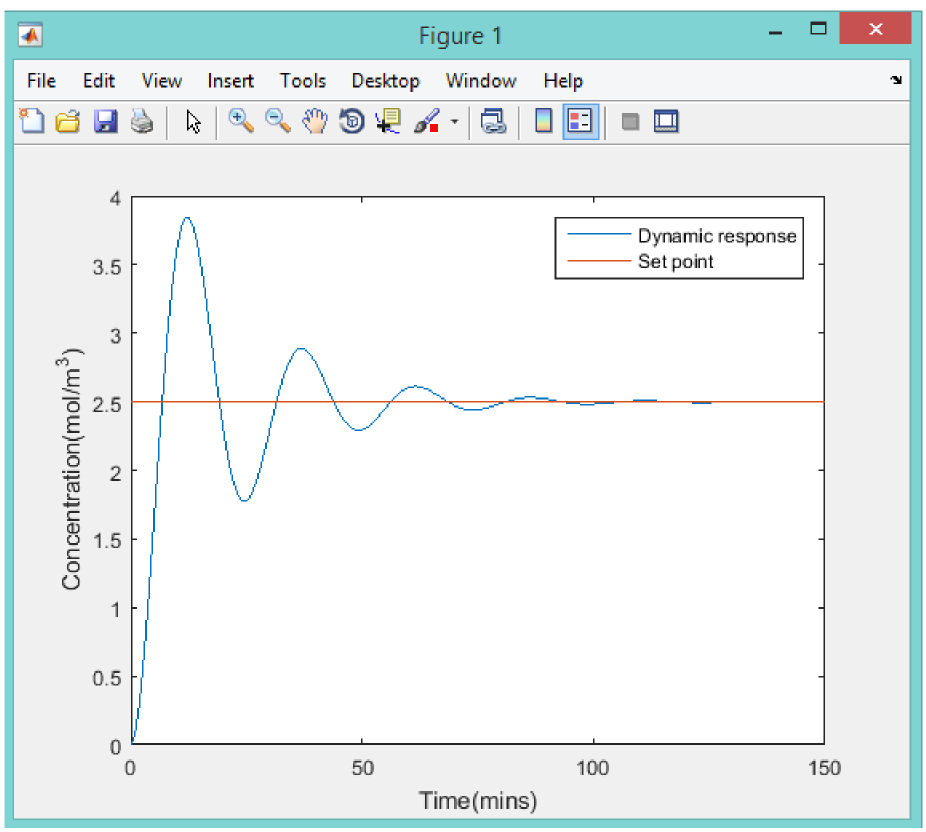

Figure 1.3: Graphical plot obtained for closed loop response for the system.