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CHE532: Process Dynamics and control II.
Assignment 2.

1a. Input $\rightarrow$ [$G_p(s)$] $\rightarrow$ Output

Isothermal liquid phase process.

$$A \xrightarrow{k} B$$

Input Variable = C_{Ai} (mol/dm³).
Output Variable = C_A (mol/dm³).
First Order reaction

$$-r_A = kC_A$$

$$r_A = -kC_A \quad r_AV \Rightarrow \text{Generation}.$$

Taking a general material balance.
Input + Generation − Output − Consumption = Accumulation.

$$\dot{m}_{in} + (r_AV) - \dot{m}_{out} = \frac{dm}{dt}$$

$$\dot{m} = \frac{mol}{dm^3} \times \frac{dm^3}{min}$$

$$\dot{m} = F \cdot C_A$$

$$m\,(mol) = \frac{mol}{dm^3} \times dm^3$$

$$m = C_AV$$

$$\frac{dm}{dt}\left(\frac{mol}{min}\right) = 1/mol$$

$$FC_{Ai} - FC_A + r_AV_A = \frac{dm}{dt}.$$

$$FC_{Ai} - FC_A - kC_AV_A = \frac{dm}{dt}.$$

$$FC_{Ai} - FC_A - kC_AV_A = \frac{d(C_A \cdot V_A)}{dt}.$$

Assuming constant volume

$$FC_{Ai} - FC_A - kC_AV_A = V_A\frac{dC_A}{dt}$$

$$V_A\frac{dC_A}{dt} = FC_{Ai} - FC_A - kC_AV_A$$

$$\frac{V_A}{F}\frac{dC_A}{dt} = C_{Ai} - C_A - \frac{kC_AV_A}{F}$$

$$\frac{V_A}{F}\frac{dC_A}{dt} = C_{Ai} - \frac{kC_AV_A}{F} - \frac{C_A}{1}.$$

$$\frac{V_A}{F}\frac{dC_A}{dt} = C_{Ai} + \left(\frac{-kC_AV_A - FC_A}{F}\right).$$

$$\frac{V_A}{F}\frac{dC_A}{dt} + \left(\frac{kC_AV_A + FC_A}{F}\right) = C_{Ai}$$

$$\frac{V_A}{F}\frac{dC_A}{dt} + \frac{FC_A + kC_AV_A}{F} = C_{Ai}$$

$$\frac{V_A}{F}\frac{dC_A}{dt} + C_A\frac{(F + kV_A)}{F} = C_{Ai}$$

dividing through by $\frac{F + kV_A}{F}$

$$\frac{V_A}{F}\frac{dC_A}{dt} \times \frac{F}{(F+kV_A)} + C_A = C_{Ai} \times \frac{F}{F+kV_A}$$

$$\frac{V_A}{F+kV_A}\frac{dC_A}{dt} + C_A = \frac{F}{F+kV_A} C_{Ai}$$

$$\tau_p \, dy/dt + y = K_p u$$

$$G_p(s) = \frac{K_p}{\tau_p s + 1}$$

$$G_p(s) = \left(\frac{F}{F+kV_A}\right) \Big/ \left(\frac{V}{F+kV_A}\right)s + 1$$

$K_p = \frac{F}{(F+kV_A)}$, $\tau_p = \frac{V_A}{(F+kV_A)}$

$K_p = \frac{0.091}{0.091 + 0.03 \times 2.5} = 0.55$

b) Given that:

$V = 2.5\,m^3$

$F = 0.091\,m^3/min$

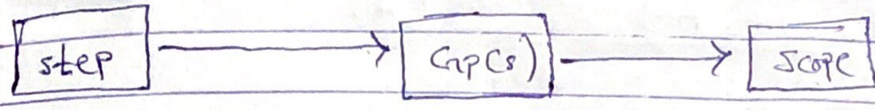
$k = 0.03\,min^{-1}$

$\tau_p = \frac{2.5}{0.091 + 0.03 \times 2.5} = 15.06$

with the aid of a matlab/simulink, run via m-file.

(i) The graphical open-loop dynamic response of the process to a 2 unit step change in the input variable applied at $t = 0.2\,min$.

$$G_p(s) = \frac{K_p}{\tau_p s + 1} = \frac{0.55}{15.06s + 1}$$

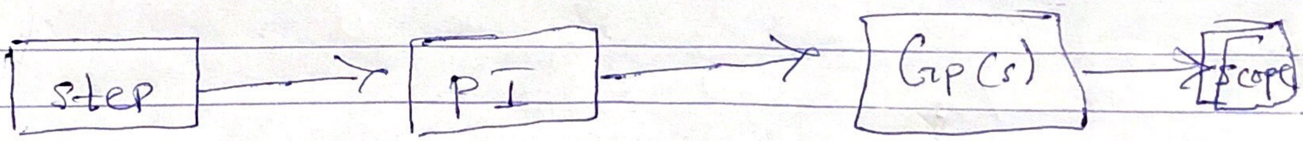


Transfer

from the analysis,
The steady state value = $K_p \Delta u$ = 0.55 x 2 = 1.1 corresponding to the graph as shown in the m-file.

Time at which it gets to steady state = $5\tau_p$ = 5 x 15.06 = 75.3s

ii Closed loop dynamic response of the process.
3 unit step change at t = 0.3min to the set-point of the output variable using a PI controller tuned with trial and error method.



V(t))