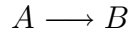


# Dynamic Model of Continuous Stirred Tank Reactor (CSTR)

The system under consideration is a Continuous Stirred Tank Reactor (CSTR) in which a non-isothermal, irreversible first order reaction



is taking place. The dynamic model for a non-isothermal CSTR is given as follows

$$\begin{aligned} \frac{dC_A}{dt} &= \frac{F}{V} (C_{A0} - C_A) - k_0 \exp\left(-\frac{E}{RT}\right) C_A \\ \frac{dT}{dt} &= \frac{F}{V} (T_0 - T) + \frac{(-\Delta H_r) k_0}{\rho C_p} \exp\left(-\frac{E}{RT}\right) C_A - \frac{Q}{V \rho C_p} \\ Q &= \frac{a F_c^{b+1}}{F_c + \left(\frac{a F_c^b}{2 \rho_c C_{pc}}\right)} (T - T_{cin}) \end{aligned}$$

Nominal parameter values of CSTR

Parameter		Value
First order reaction rate constant	$k_0$ ( $min^{-1}$ )	$10^{10}$
Inlet concentration of A	$C_{A0}$ ( $kmol/m^3$ )	2.0
Steady state flow rate of A	$F$ ( $m^3/min$ )	1.0
Density of the reagent A	$\rho$ ( $g/m^3$ )	$10^6$
Specific heat capacity of the reagent A	$C_p$ ( $cal/g^0C$ )	1.0
Heat of reaction	$\Delta H_r$ ( $cal/kmol$ )	$-130 * 10^6$
Density of the coolant	$\rho_c$ ( $g/m^3$ )	$10^6$
Specific heat capacity of the coolant	$C_{pc}$ ( $cal/g^0C$ )	1.0
Volume of the CSTR	$V$ ( $m^3$ )	1.0
Coolant flow rate	$F_c$ ( $m^3/min$ )	15
Reactor temperature	$T$ ( $K$ )	393.954
Reactor concentration of A	$C_A$ ( $kmol/m^3$ )	0.265
	$E/R$ ( $K^{-1}$ )	8330
	$b$	0.5

Classificatoin of Variables

State Variables	$C_A, T$
Manipulated Inputs	$F, F_c$
Disturbances	$C_{A0}, T_0, T_{cin}$
Parameters	$k_0, \rho, \rho_c, C_p, C_{pc}, \Delta H_r, V, E/R, a, b$

This system exhibits entirely different dynamic characteristics for different set of parameters values and operating conditions

- Single stable steady state:

Model Parameter	$a$	$1.678e10^6$
Inlet temperature of the coolant	$T_{cin} (K)$	365
Inlet temperature of A	$T_0 (K)$	323

Concentration ( $C_A$ ): 0.2646 mol/m<sup>3</sup> and Temperature(T): 393.95 K

- Multiple Steady States

Model Parameter	$a$	0.516e6
Inlet temperature of the coolant	$T_{cin} (K)$	343
Inlet temperature of A	$T_0 (K)$	310

Stable Steady State:

Concentration ( $C_A$ ): 0.1598 mol/m<sup>3</sup> and Temperature: 404.736 K

Unstable Steady State:

Concentration ( $C_A$ ): 1.3718 mol/m<sup>3</sup> and Temperature: 349.905 K

Stable Steady State:

Concentration : 1.7895 mol/m<sup>3</sup> and Temperature: 331.008 K

- Single Unstable Steady State

Model Parameter	$a$	0.516e6
Inlet temperature of the coolant	$T_{cin} (K)$	365
Inlet temperature of A	$T_0 (K)$	323

Concentration: 1.0587 mol/m<sup>3</sup> and Temperature: 359.936 K

**Run MATLAB file `ctr_sim.m` to perform open loop dynamic simulation of the above system at various operating points**