Universidad Nacional de Colombia
Facultad de Minas
Introduction to Process Control
NON-ISOTHERMAL CSTR

1 INTRODUCTION

The continuous stirred tank reactor (CSTR) is a common chemical system used in the process industry for producing various products, treating materials, supporting microbial growth, among other applications. A single, irreversible, first-order exothermic reaction, $A \rightarrow B$, takes place in the vessel, which is assumed to be perfectly mixed at all times. The inlet stream of reagent A enters the tank at a constant volumetric rate, F. The product stream B exits continuously at the same volumetric rate, and liquid density is constant. Thus, the volume of reacting liquid V is constant.

Since the reaction is exothermic, it is strictly required to implement a suitable temperature control within the vessel that prevents thermal runaway. One typical option is to use a cooling jacket surrounding the vessel, in which the cooling temperature T_c is a manipulated variable, i.e., it constitutes the control input. Figure 1 shows a schematic diagram of such system.

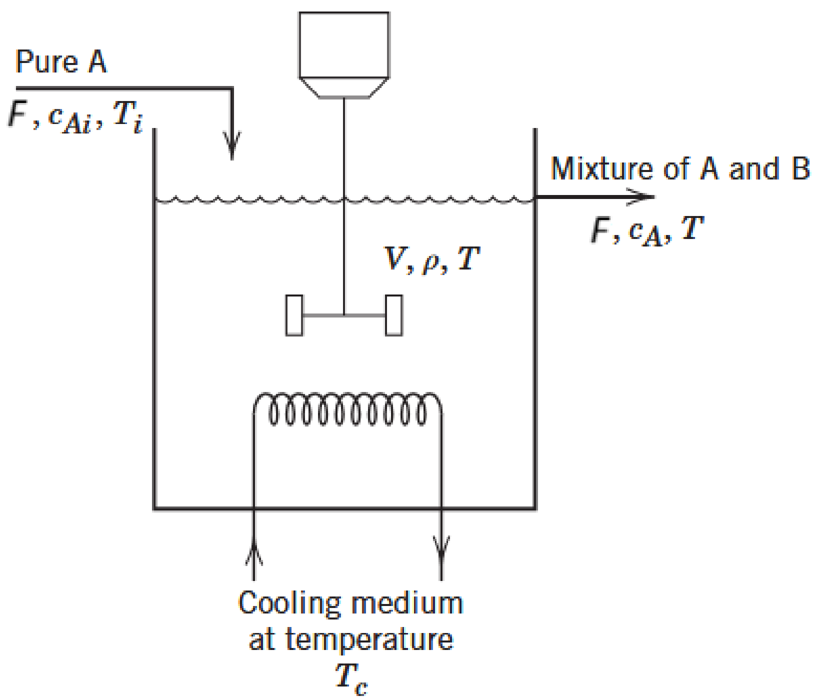

Figure 1: Jacketed CSTR

Feed concentration C_{Ai} and temperature T_i are normally assumed to be constant unmeasured disturbances. The model has two states: C_A, the concentration of reagent A in the reactor, and T, the temperature in the reactor, with the latter being the only measured variable due to the lack of concentration sensors.

Design parameters and operating conditions are given below:

In the model, the initial value of C_A is 8.5698 kmol/m^3 and the initial value for T is 311.2639 K. This operating point is an equilibrium when the inflow feed concentration C_{Ai} is 10 kmol/m^3, the inflow feed temperature T_i is 300 K, and the coolant temperature T_c is 292 K.

Table 1: Design parameters for the CSTR

Parameter	**Value**	**Unit**	**Description**
F	1	m^3/h	Volumetric flow rate
V	1	m^3	Reactor volume
R	1.985875	kcal/(kmol·K)	Ideal gas constant
ΔH	-5960	kcal/kmol	Heat of reaction per mole
E	11843	kcal/kmol	Activation energy per mole
A	34930800	1/h	Pre-exponential nonthermal factor
ρC_p	500	kcal/(m^3·K)	Density times heat capacity
UA	150	kcal/(K·h)	Overall heat transfer coefficient times area

2 PROJECT

Based on this information, structure your report around the following questions:

1. (0.8) General description
   - (0.5) Describe the components of a CSTR such as: motor, piping, baffles, pumps, sensors, actuators. Include references.
   - (0.3) Look in the literature (not AI platforms) five real applications of a CSTR in the chemical or biochemical industry. Include references. Note: Do not rely on AI platforms for this section; prioritize peer-reviewed and industrial literature.
2. (0.8) Representation
   - (0.2) Describe the nonlinear model for the system.
   - (0.3) Describe the linearized version of the model.
   - (0.3) Find the transfer function from coolant temperature to reactor temperature relating the reactor temperature with the coolant temperature, $\frac{T(s)}{T_c(s)}$, from feed concentration to reactor temperature, $\frac{T(s)}{C_{Ai}(s)}$, and from feed temperature to reactor temperature $\frac{T(s)}{T_i(s)}$.
3. (1.0) Open-loop analysis
   - (0.3) Internal and BIBO stability analysis.
   - (0.7) Dynamic response of the output variable when a step excitation is applied to the input and/or the disturbances. A comprehensive comparison must be made for the nonlinear system, the linearized system and the system described by transfer functions.
4. (1.4) Closed-loop analysis
   - (0.2) Controller selection and tuning method.
   - (0.3) Stability and performance analysis.
   - (0.4) Dynamic response during reference change (evolution of the output variable, control input and error). Comparison between the linear and nonlinear systems.
   - (0.5) Dynamic response during disturbance rejection (evolution of the output variable, control input and error). Comparison between the linear and nonlinear systems.
5. (0.5) Matlab use
   - Matlab-Simulink communication.
   - Plots.
6. (0.5) Teamwork

References

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[3] H. A. Botero, E. Jiménez-Rodríguez, O. Jaramillo, and J. D. Sánchez Torres, "Robust estimation for a cstr using a high order sliding mode observer and an observer-based estimator," *Revista Ion*, vol. 29, no. 2, pp. 101–112, 2016.

[4] apmonitor.com, "Transient (dynamic) modeling in matlab / simulink," https://www.youtube.com/watch?v=dJuD2wiQbts, 2013, youTube video, accessed 2025-06-23.

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