Koya University
Faculty of Engineering
Chemical Engineering Department

Reactor Design Laboratory

Exp-6

Group-D

Single CSTR

Prepared by:
Twana Dler
Muhamad kazim
Ali Hiwa

Supervised by:
mr. Blnd zrar

Table of content :

Aim :

To determine conductivity inside the CSTR Reactor and use it to calculate the CSTR's Conversion .

Introduction :

A Continuous Stirred-Tank Reactor (CSTR) is one of the most widely used reactor types in chemical and process industries. It is designed to operate at steady-state conditions, where reactants are continuously fed into the reactor, and products are continuously removed. The reactor is equipped with an agitator or stirrer, ensuring thorough mixing and uniform composition throughout the system. Due to this complete mixing, the exit stream has the same concentration as the reactor contents.

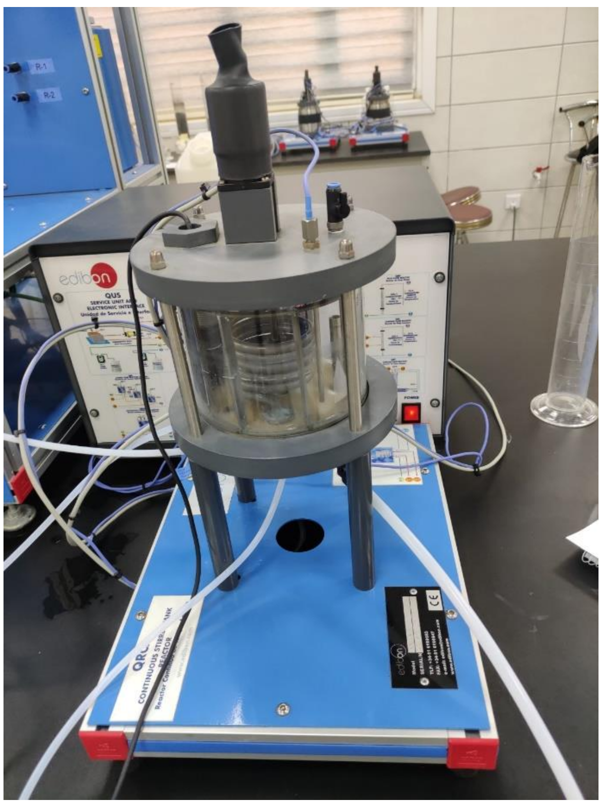
CSTRs are commonly used in liquid-phase reactions, such as polymerization, fermentation, and neutralization processes, as well as in some gas-phase reactions when efficient mixing is required. The reactor is particularly suitable for reactions requiring precise temperature control, as the well-mixed nature facilitates efficient heat exchange. However, compared to other reactor types, such as the Plug Flow Reactor (PFR), a CSTR generally requires a larger volume to achieve the same level of conversion, making it less efficient for high-conversion applications.

Due to its simple design and ease of operation, the CSTR remains a fundamental reactor in both industrial applications and academic research, serving as a benchmark for reactor modeling and performance evaluation.

Equipment:

- ✓ Service unit
- ✓ Control interface
- ✓ One CSTR
- ✓ Conductivity meter
- ✓ Bottle

CSTR



conductivity meter:

Procedure :

1-we connect the input stream to the bottom of the CSTR .

2-and about output stream we connect the first end to the bottom of the reactor and the second end to an empty Bottle.

3-then we turn on the main switch and open the flow valve.

4- the feed does not enter until we open the vent valve due to pressure compress .

5-after opening the vent we turn on the pump to pump the solutions to the CSTR then we turn on the stirrer.

6- the feeds enters and the conversion happens.

7-the level of the fluid stops increasing when it gets to the over flow limit which a small pipe inside CSTR linked to the output stream.

8- after reaching to the overflow limit, we close the vent valve.

9-during this reaction we read the electric conductivity .

10-if we finish we turn off the pumps, stirrer and close the flow valve.

11- at the end we drain the reactor by opening the drain value in the bottom and vent valve at the top of the reactor.

Safety precautions:

Safety Precautions for Operating a CSTR with CH_3COOH and NaOH in a Lab

When using a Continuous Stirred-Tank Reactor (CSTR) with acetic acid (CH_3COOH) and sodium hydroxide (NaOH) as reactants, safety is crucial due to the corrosive nature of NaOH and the reactivity of the acid-base neutralization reaction. Below are key safety precautions to follow:

1. Personal Protective Equipment (PPE)

☑ Wear safety goggles – Protects eyes from splashes.

☑ Use chemical-resistant gloves – Prevents skin burns from NaOH and CH_3COOH.

☑ Wear a lab coat – Shields skin from accidental spills.

☑ Closed-toe shoes – Prevents exposure to corrosive substances.

2. Chemical Handling & Storage

- NaOH (Sodium Hydroxide):
  - Highly corrosive; can cause severe burns.
  - Store in a tightly sealed container to prevent moisture absorption.
  - Always add NaOH to water, never the reverse, to avoid heat generation.

- CH_3COOH (Acetic Acid):
  - Can be irritating to the skin and eyes.
  - Store away from strong bases and oxidizing agents.

3. Reactor Operation Safety

⚠ Check Equipment Before Use – Inspect stirrer, feed lines, and seals for leaks.

⚠ Slow Addition of Reactants – To control heat and avoid rapid reaction.

⚠ Monitor Temperature & pH – The reaction is exothermic, so overheating can occur.

⚠ Ensure Proper Ventilation – Acetic acid fumes can be irritating; use a fume hood if necessary.

⚠ Avoid Overpressure – Ensure that the reactor has a proper vent or relief system.

4. Emergency Procedures

🚨 Spill Management:

- For NaOH spills – Neutralize with dilute acetic acid.
- For CH_3COOH spills – Neutralize with sodium bicarbonate solution.
- For skin contact – Rinse immediately with plenty of water and seek medical attention if irritation persists.
- For eye exposure – Rinse with water for at least 15 minutes and get medical help.

Fire Hazard:

- Acetic acid is flammable, so keep it away from ignition sources.
- Have a fire extinguisher (CO_2 or dry chemical) nearby.

Advantage & disadvantage:

Advantages of CSTR:

A major advantage of a CSTR is its ability to maintain a uniform composition and temperature due to continuous mixing, ensuring steady-state operation. It allows for precise control over reaction conditions, making it suitable for reactions that require constant temperature regulation, such as highly exothermic or endothermic processes. The continuous operation of a CSTR simplifies automation and integration into industrial production lines, leading to a steady output of products. It is also useful for handling liquid-phase reactions and can accommodate reactions with slow kinetics by allowing an extended residence time. Additionally, multiple CSTRs can be used in series to improve conversion efficiency.

Disadvantages of CSTR:

One of the main disadvantages is that CSTRs generally require a larger volume than Plug Flow Reactors (PFR) to achieve the same level of conversion, making them less space-efficient. The constant mixing results in lower reactant concentrations, which can lead to slower reaction rates compared to other reactor types. Energy consumption for agitation and maintaining uniformity can also be high, increasing operational costs. Another limitation is that back-mixing can reduce overall conversion efficiency, especially for reactions where high conversion per pass is desired. Additionally, scale-up can be complex due to the challenges in maintaining ideal mixing and flow patterns in large reactors.

Conclusion:

The experiment on a single Continuous Stirred Tank Reactor (CSTR) demonstrated its ability to maintain uniform concentration and temperature due to continuous mixing. By analyzing the reactor's performance, we observed how residence time, flow rate, and reaction kinetics influence conversion efficiency. The results highlighted that while a CSTR provides steady-state operation and ease of control, its mixing characteristics can lead to lower reactant concentrations, affecting reaction rates. Overall, the experiment reinforced the importance of optimizing operating conditions to enhance efficiency, making CSTRs suitable for industrial applications where continuous processing and controlled reaction environments are required.

Discussion:

(Twana Dler)

1- **Why is continuous mixing important in a CSTR, and how does it affect reactor performance?**

Continuous mixing ensures a uniform concentration and temperature throughout the reactor, preventing concentration gradients and improving reaction control. This leads to steady-state operation, making it easier to regulate process conditions. However, complete mixing also results in lower reactant concentrations compared to other reactors, which can reduce reaction rates and overall conversion efficiency.

2- **How does residence time influence the conversion in a CSTR?**

Residence time is a key factor in determining the extent of reaction completion. A longer residence time allows reactants to stay in the reactor for a sufficient duration, leading to higher conversion. However, due to continuous mixing, the concentration of reactants remains lower, meaning that even at long residence times, conversion may not reach the levels achieved in a Plug Flow Reactor (PFR).

3- **What are the limitations of a single CSTR in achieving high conversion?**

A single CSTR has inherent limitations due to back-mixing, which results in incomplete conversion per pass. To achieve high conversion, a larger reactor volume or multiple CSTRs in series may be required. Additionally, the lower reactant concentration caused by mixing can slow down reaction rates, making it less efficient for reactions requiring high conversion per unit volume.

4- **How does flow rate affect the performance of a CSTR?**

Flow rate directly influences the residence time of reactants in the reactor. A higher flow rate reduces residence time, leading to lower conversion since reactants have less time to react. Conversely, a lower flow rate increases residence time, potentially improving conversion but also requiring careful control to prevent undesirable side reactions or excessive accumulation of products.

5-What are the key factors to consider when designing a single CSTR for a specific reaction?

When designing a single CSTR, important factors include reactor volume, residence time, mixing efficiency, and heat transfer requirements. The reactor must be sized appropriately to ensure sufficient residence time for the desired conversion. Proper mixing is essential to maintain uniform concentration and temperature, preventing dead zones or short-circuiting. Heat transfer considerations are also crucial, especially for highly exothermic or endothermic reactions, to maintain stable operating conditions. Additionally, material selection should account for corrosion resistance and chemical compatibility with the reactants and products.

6-How does the experimental data compare with theoretical predictions for a CSTR?

The experimental data typically show that conversion in a single CSTR is lower than theoretical predictions for ideal reactors, primarily due to non-ideal flow patterns, mixing inefficiencies, and potential dead zones. Deviations from theory can also result from measurement errors, equipment limitations, or variations in operating conditions. Comparing experimental results with theoretical models helps in understanding reactor performance and identifying areas for optimization.