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RE9: Residence Time Distribution

1 Introduction

The purpose of this experiment is to study the residence time in a non-reactive system, and understand how a real reactor differs from an ideal plug flow reactor (PFR). This is done by measuring the concentration of an injected tracer, methylene blue, before and after the reactor. The residence time distribution (RTD) will be found using the measured quantities, and then compared with the residence time of a PFR.

2 Theory[1]

The *residence time distribution* (RTD) for a real reactor can be determined experimentally by injecting an optical tracer to the reactor. As the tracer moves through the reactor, the concentration of trace leaving at time t is measured. E(t) is commonly used to measure RTD, and is given as:

$$E(t) = \frac{c(t)}{\int_0^\infty c(t)dt} \tag{2.1}$$

As E(t) is a probability density distribution, it has to equal 1.

$$\int_0^\infty E(t)dt = 1 \tag{2.2}$$

Mean residence time can be calculated by the following equation,

$$\bar{t} = \int_0^\infty tE(t)dt \tag{2.3}$$

The integrals are solved using the trapezoidal rule.

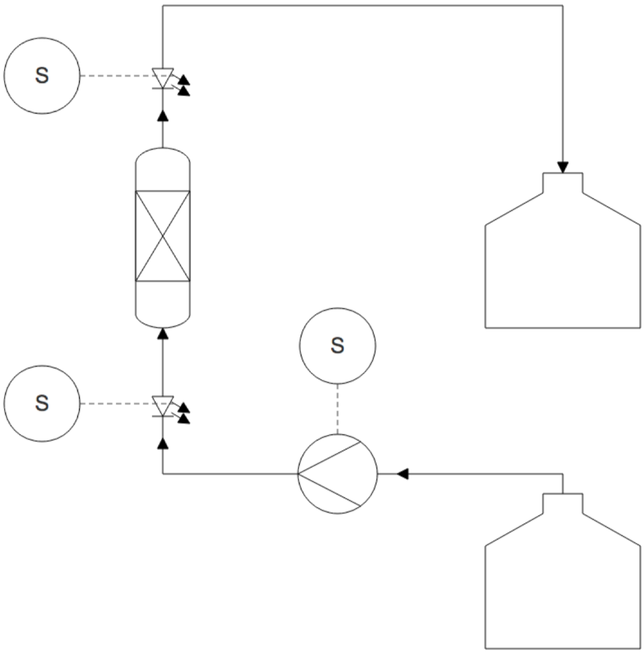
The voltage measured by the light sensors can be used to determine the concentration of trace leaving the reactor.

$$\Delta U_T(t) = \beta_T \cdot c(t) \tag{2.4}$$

$$\Delta U_B(t) = K_B(1 - e^{-\frac{c(t)}{\tau_{p,B}}}) \tag{2.5}$$

3 Experimental Procedure[1]

Figure 3.1 shows the experimental setup with deionized water being pumped from the first tank, through a reactor, and into the waste tank. The tracer is injected after the pump and before the first sensor.



Figur 3.1: Experimental setup.

3.1 Determination of RTD

1. Prepare three different methylene blue solutions (250 mL), with concentrations ranging from 10-150 $\mathrm{mg\,L^{-1}}$.This is done by dissolving the appropriate amount of salt in deionized water, using volumetric flasks.
2. For each of the three solutions, inject quickly into the stream of deionized water using a syringe.
3. Each solution will be injected three times at three different pump rates in the range 400-1200 RPM, using the same three pump rates for every solution.

3.2 Determination of Volumetric Flow Rate

1. Fill a measuring cylinder with a known volume of deionized water (V_{cal}).
2. Start the pump and register the time (t_{cal}) it takes to consume the known volume. Use the same three pump rates as before.
3. Take two samples for each pump rate (6 in total).

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Referanser

[1] Re9: Residence time distribution, 2021. URL https://folk.ntnu.no/preisig/HAP_Specials/Felles_lab/Experiments/RE9_milli-reactor_residence_time.pdf. Hentet 13.10.21 .

[2] Mikael Hammer. Risk assessment: Felleslab, 2015, re9 milli reactor residence time, 2015. Hentet 13.10.21 .

A Calculations

A.1 Mass Required to Make Solutions

The mass, m, required to make the three solutions is given by:

$$m = c \cdot V, \tag{A.1}$$

where c is the desired concentration of the solution and V is the volume of said solution. Each solution is going to have a volume of 250 mL and concentrations ranging from 10-150 $\mathrm{mg\,L^{-1}}$. The calculated masses needed for each sample is shown in table A.1:

Tabell A.1: Calculated masses needed for specific concentrations, for each sample.

Sample	c [$\mathrm{mg\,L^{-1}}$]	V [L]	m [mg]
1	25	0.25	6.25
2	50	0.25	12.5
3	100	0.25	25

A.2 Volumetric Flow Rate

The volumetric flow rate, q, can be calculated by:

$$q = \frac{V_{cal}}{t_{cal}}, \tag{A.2}$$

where V_{cal} is the known volume of deionized water and t_{cal} is the time it takes to consume said volume.

B Risk Assessment

Lab coat and goggles should be worn at all times. When handling methylene blue, gloves should be worn, as the blue colour is difficult to get rid of. The risk of spilling substances in this experiment is quite low. Breakage of equipment is likely, however it will not have any large consequences, and therefore it is not a big risk in this experiment. [2]

Surplus methylene blue solution with high concentration is to be disposed in the waste container marked with organic solvents with halogene. Mixture of methylene blue solution and water from experiments (extremely diluted, c«1 $\mathrm{mg\,L^{-1}}$) can be disposed of in the sink. [1]